

Carbon Pricing and Its Potential Impact on Reserves

September 4, 2019

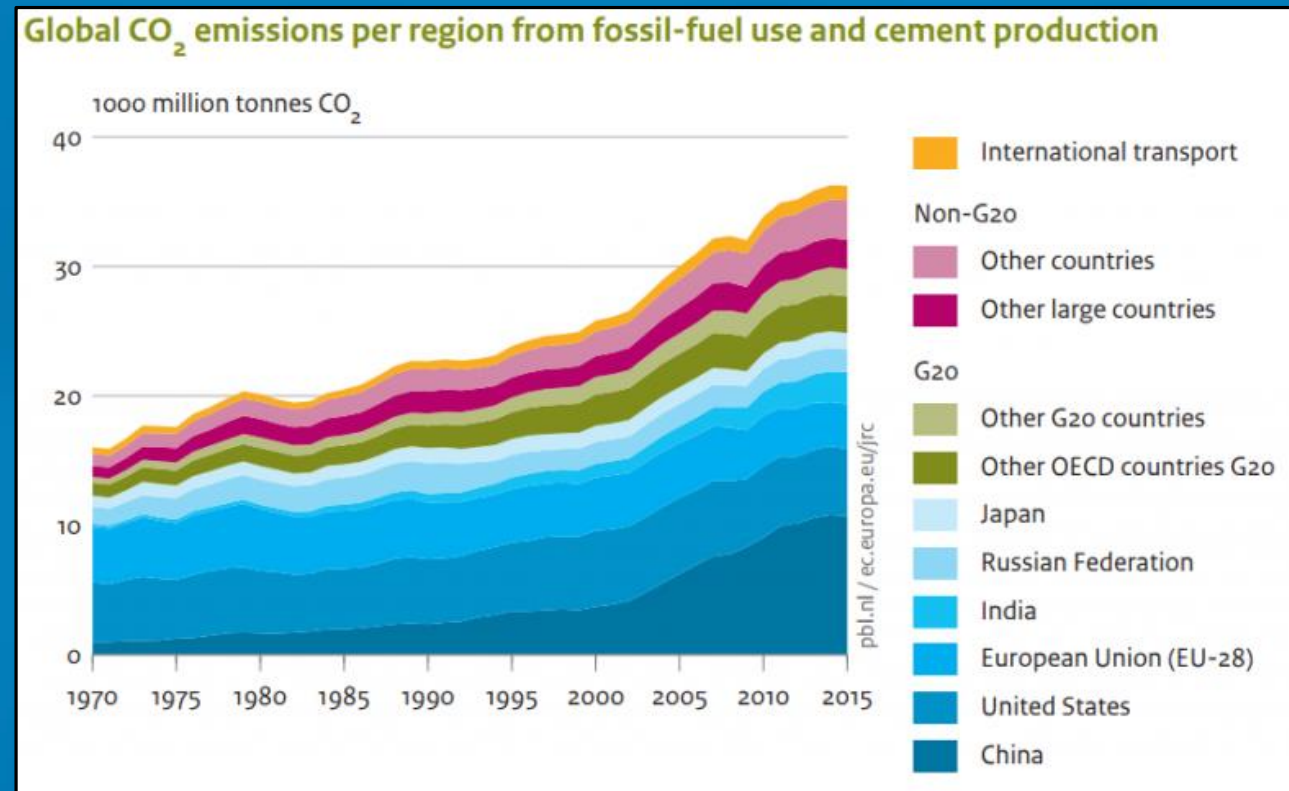
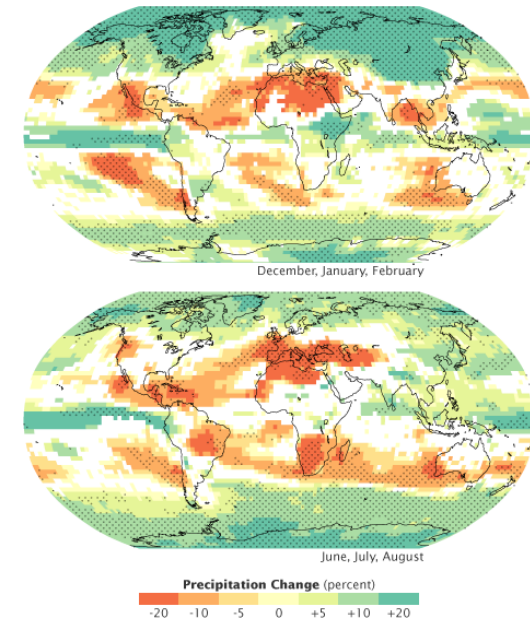
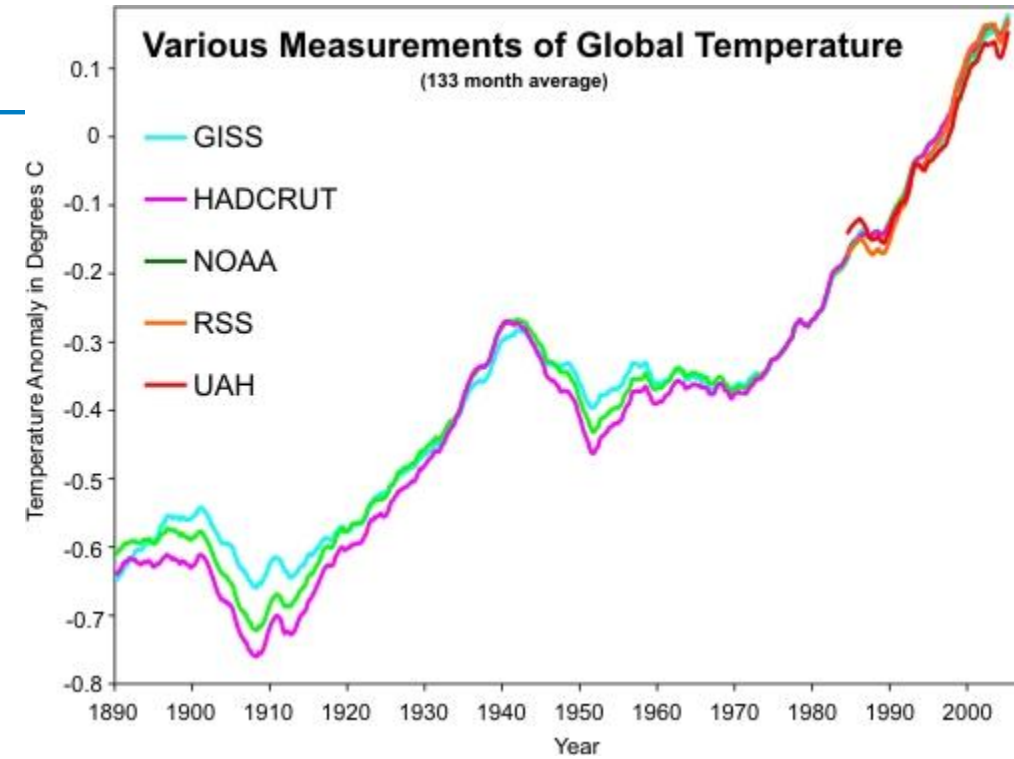


Image source: <https://www.downtoearth.org.in/news/climate-change/global-carbon-emissions-remained-static-in-2016-58775>

Global Warming and Climate Change

These two terms refer to two different physical phenomena

- ❑ "Global warming" is the increase in Earth's average surface temperature due to rising levels of greenhouse gases
- ❑ "Climate change" is a long-term change in the Earth's climate, or of a region on Earth
 - Changes to precipitation patterns and sea level are likely to have much greater human impact than the higher temperatures alone



Historical Weather Discussion

Titania, *A Midsummer-Night's Dream*, Shakespeare (1595)

“And thorough this distemperature we see
The seasons alter: hoary-headed frosts
Fall in the fresh lap of the crimson rose,
And on old Hiems' thin and icy crown
An odorous chaplet of sweet summer buds
Is, as in mockery, set. The spring, the summer,
The chiding autumn, angry winter, change
Their wonted liveries, and the mazèd world
By their increase now knows not which is which.”



Edwin Landseer, *Scene from A Midsummer Night's Dream*, National Gallery of Victoria

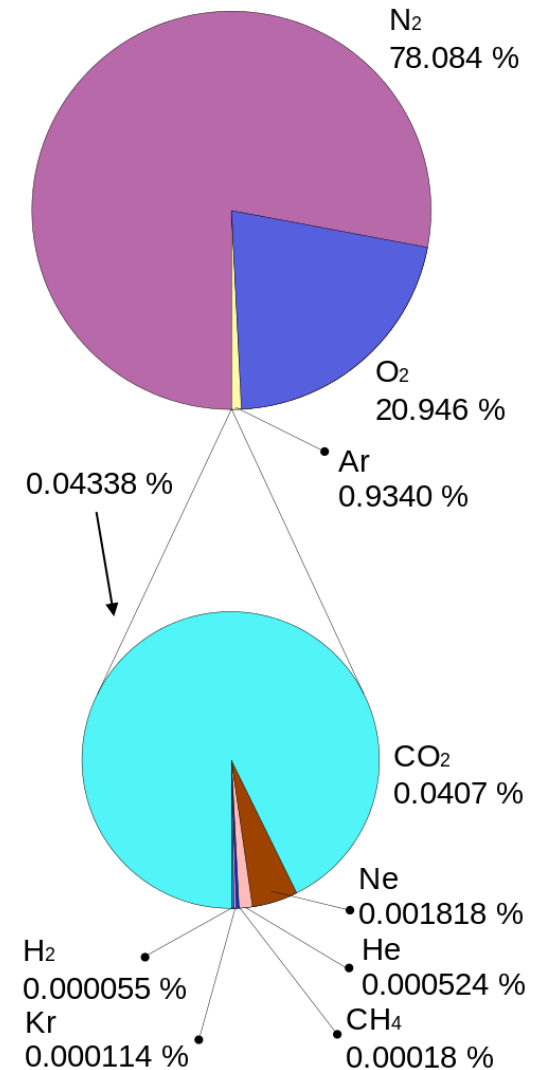
Titania's allusions to seriously bad weather show Elizabethans' perplexity at these seasonal disorders, which ruined crops, causing food shortages, which, in turn, resulted in hunger, inflation and disease

Agenda

- ❑ What are greenhouse gases (GHG)?
- ❑ What is the greenhouse effect?
- ❑ How are GHG emissions measured?
- ❑ Sources of GHG emissions: worldwide and oil and gas industry
- ❑ Carbon pricing
- ❑ Potential impact on reserves

What are Greenhouse Gases?

- ❑ A **greenhouse gas** (abbreviated **GHG**) is a gas that absorbs and emits radiant energy within the thermal infrared range
- ❑ The primary greenhouse gases in Earth's atmosphere are **water vapor**, **carbon dioxide**, **methane**, **nitrous oxide** and **ozone**
 - They are all naturally present in the atmosphere
 - Without greenhouse gases, the average temperature of Earth's surface would be about $-18\text{ }^{\circ}\text{C}$ ($0\text{ }^{\circ}\text{F}$), rather than the present average of $15\text{ }^{\circ}\text{C}$ ($59\text{ }^{\circ}\text{F}$)
- ❑ Other GHGs are synthetic chemicals that are emitted only as a result of human activity



What are Greenhouse Gases?

- ❑ Carbon dioxide (CO₂) is the most important greenhouse gas because it exists in the highest quantity in the atmosphere
- ❑ Other gases have a much higher greenhouse effect, but exist in much lower concentrations
 - Methane has 25 times the effect of an equivalent volume of CO₂, but there is only about 1/225 as much
 - The current concentration of CO₂ is about 400 parts per million (ppm), up from ~230 ppm in the pre-industrial era
- ❑ Combustion of methane
$$\text{CH}_4 + 2\text{O}_2 = \text{CO}_2 + 2\text{H}_2\text{O}$$

Greenhouse Gas		Global Warming Potential (GWP)
1.	Carbon dioxide (CO ₂)	1
2.	Methane (CH ₄)	25
3.	Nitrous oxide (N ₂ O)	298
4.	Hydrofluorocarbons (HFCs)	124 – 14,800
5.	Perfluorocarbons (PFCs)	7,390 – 12,200
6.	Sulfur hexafluoride (SF ₆)	22,800
7.	Nitrogen trifluoride (NF ₃) ³	17,200

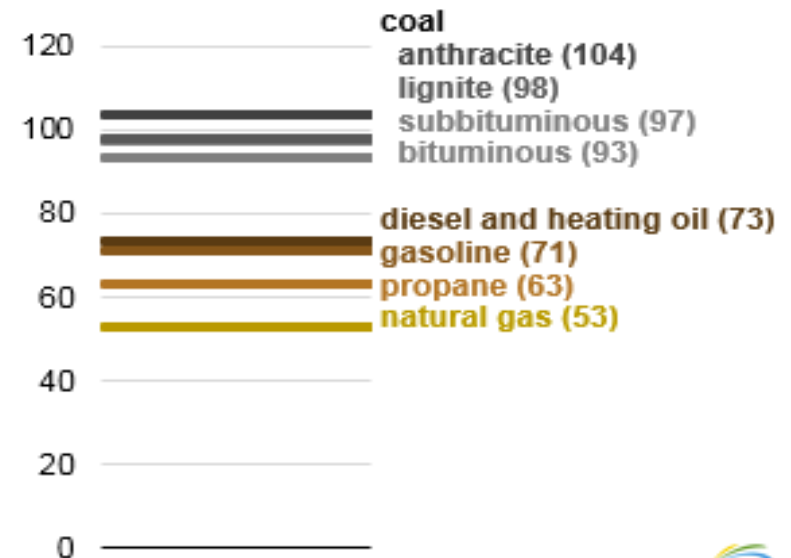
- ❑ Carbon dioxide – burning fossil fuels, removed by plants
- ❑ Methane – livestock and coal, oil and gas industry
- ❑ Nitrous oxide – anesthetic (“laughing gas”) and fertilizer
- ❑ Hydrofluorocarbons (HFCs) – used in air conditioning and as refrigerants
- ❑ Perfluorocarbons (PFCs) – used as refrigerants, solvents and anesthetics
- ❑ Sulphur Hexafluoride – magnesium production and filling for double-paned windows
- ❑ Nitrogen trifluoride - used as an etchant in microelectronics

What are Greenhouse Gases?

- ❑ Greenhouse gases are measured and reported in terms of the effect of an **equivalent volume of CO₂** according to their global warming potential (GWP)
 - Grams of carbon dioxide equivalent (gCO₂e)
- ❑ That is why we talk about “**carbon emissions**”, even though not all GHGs contain carbon
- ❑ **Carbon intensity** is a measure of the carbon equivalent emission compared with the industrial activity
 - Grams of carbon dioxide equivalent released per megajoule of energy produced (gCO₂e/MJ)
 - Kilograms of carbon dioxide equivalent released per barrel of oil produced (kgCO₂e/bbl)

Gas	Chemical formula	Half-Life (years)	Global warming potential for given time horizon		
			20-yr	100-yr	500-yr
Carbon dioxide	CO ₂	30–95	1	1	1
Methane	CH ₄	12	72	25	7.6
Nitrous oxide	N ₂ O	114	289	298	153

Carbon intensity of selected fuels
kilograms CO₂ per million British thermal units



❑ For the oil

Crude oil has a density of around 850 kg/m³ (35 °API) [range <800 (light) to >920 kg/m³ (heavy)]

❑ Crude oil consists of 83% to 87% carbon (by weight)

❑ Assuming a density of 850 kg/m³, **one barrel of oil** (159 liters) would weigh 135 kg, which contains at 85% carbon (at the mid-point) **115 kg of carbon**

❑ For the carbon dioxide

Carbon atomic weight: 12.0 g/mol

Oxygen atomic weight: 16.0 g/mol

Carbon dioxide: carbon = 12 plus 2 x oxygen = 2 x 16 = 32 => Total: **44 g/mol**

(mass of carbon: 12/44 = 27.27% of carbon in CO₂)

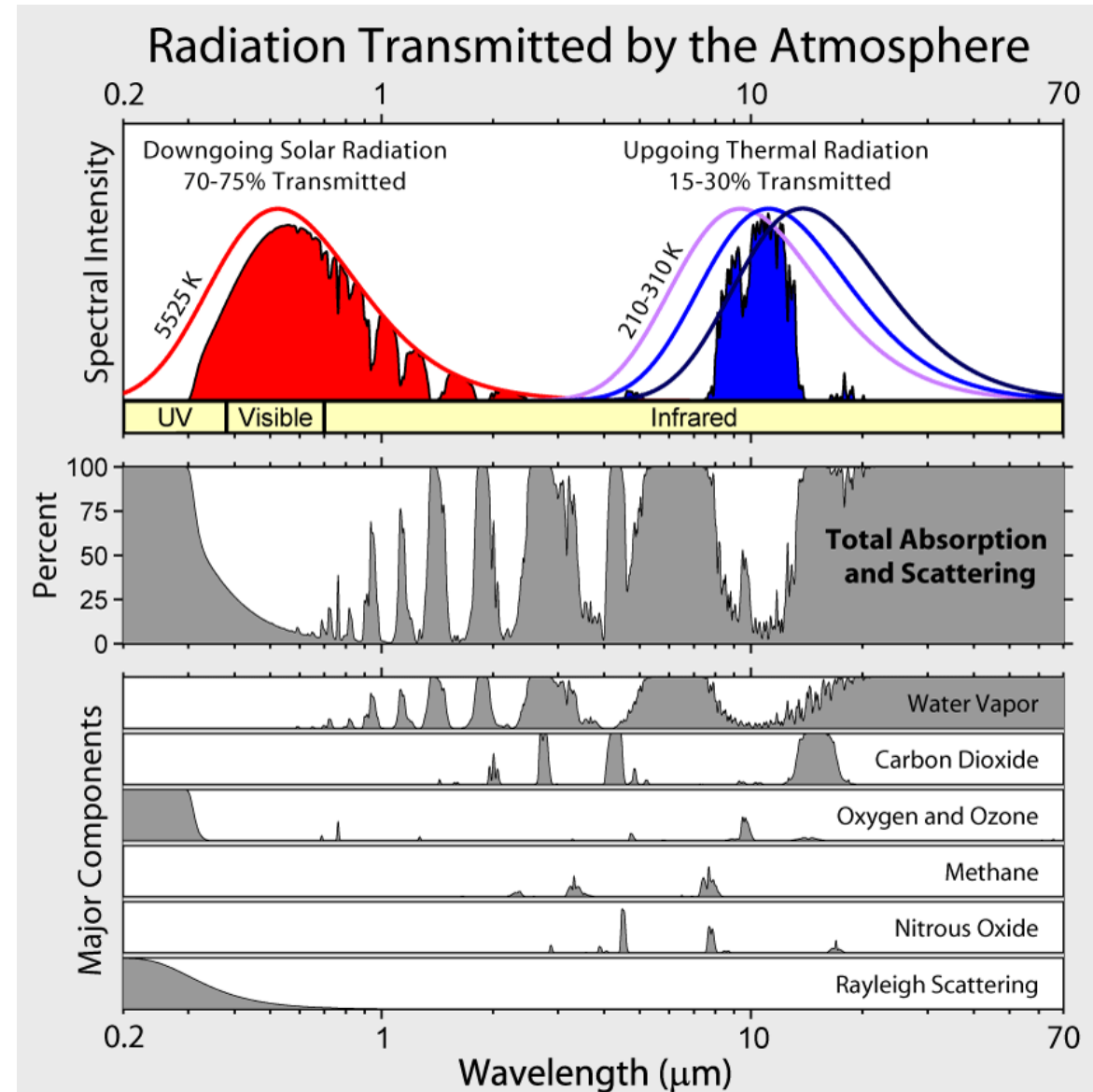
❑ Mass of carbon dioxide: 115 kg carbon / 0.2727 = **422 kg CO₂ / bbl**

❑ Burning 100 MMbopd => 1.54 x 10¹⁰ tCO₂ = **15.4 GtCO₂** a year

❑ Total world emissions are about **37 GtCO₂** a year

What is the Greenhouse Effect?

- ❑ The Sun emits electromagnetic radiation that peaks in the visible region—corresponding to a temperature of $\sim 5,500$ K
- ❑ Emissions from the Earth vary, but always peak in the infrared
- ❑ The position and number of absorption bands are determined by the chemical properties of the gases present
- ❑ Water vapor is the most significant of these greenhouse gases, followed by carbon dioxide and various other minor greenhouse gases
- ❑ Collectively these processes capture and redistribute 25-30% of the energy in direct sunlight passing through the atmosphere
- ❑ By contrast, the greenhouse gases capture 70-85% of the energy in up-going thermal radiation emitted from the Earth's surface

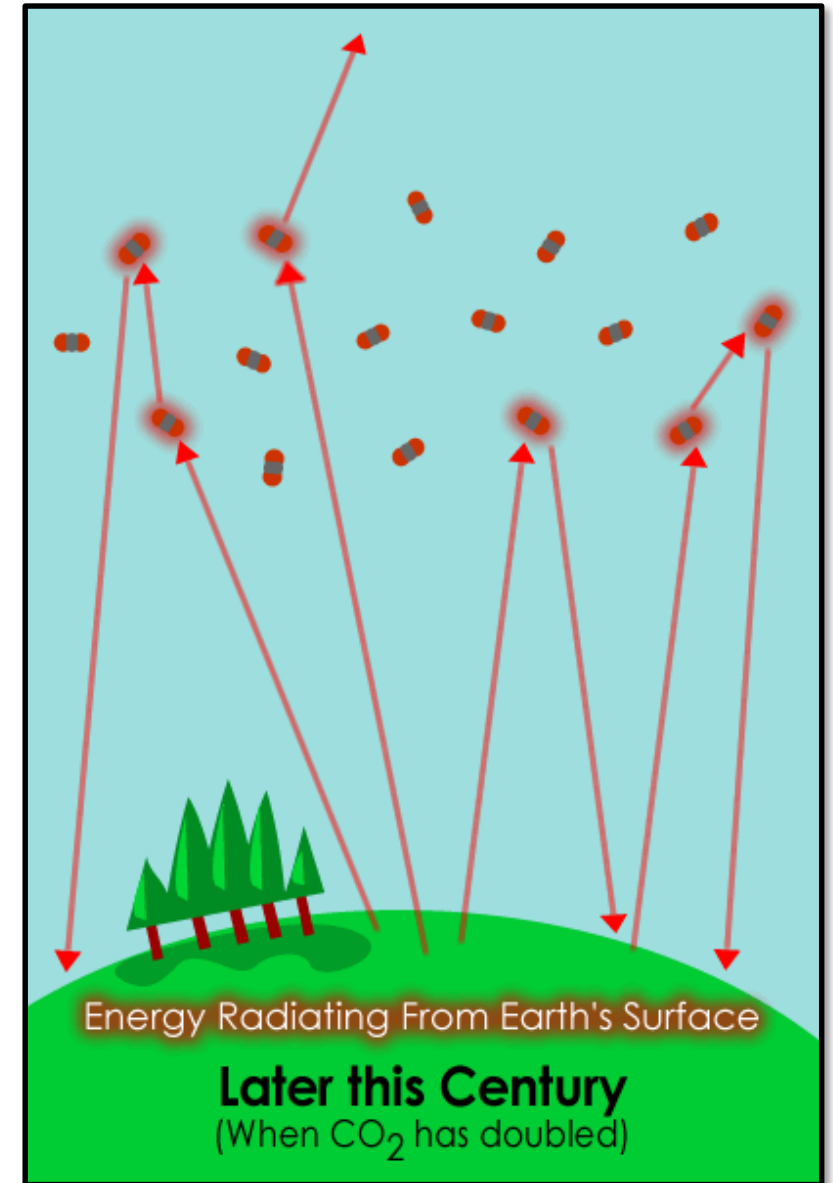
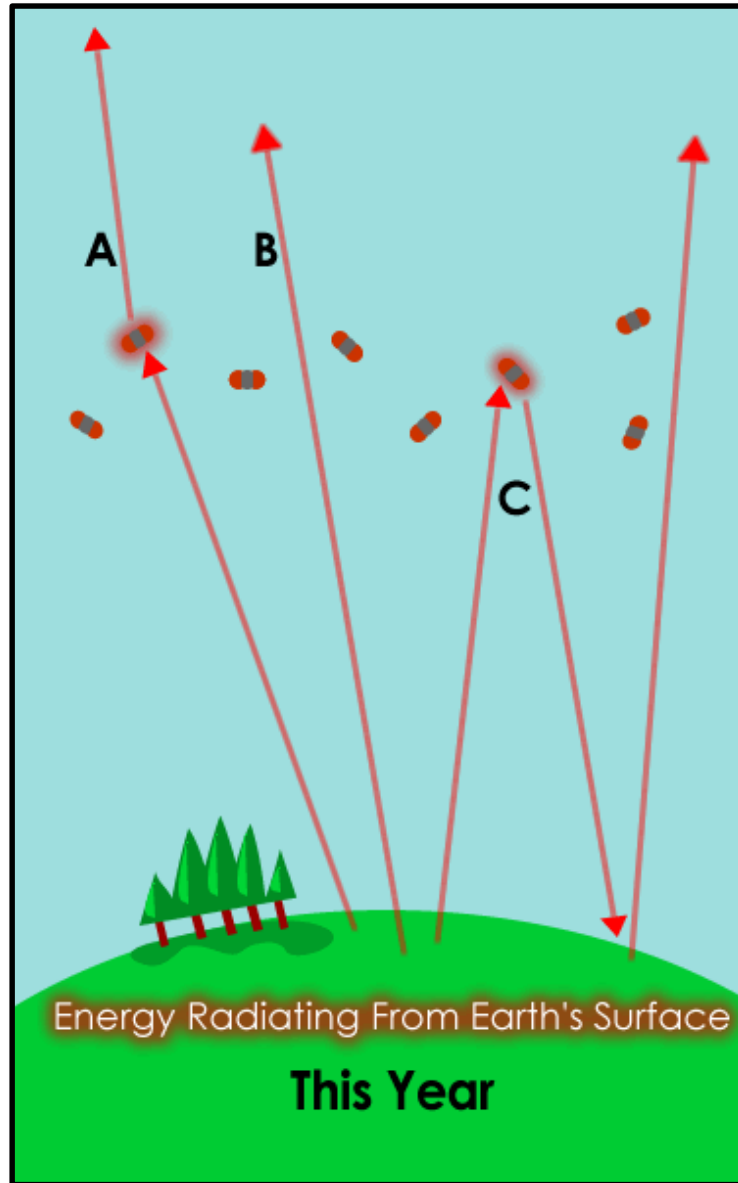


What is the Greenhouse Effect?

The Earth's surface, warmed by the Sun, radiates heat into the atmosphere

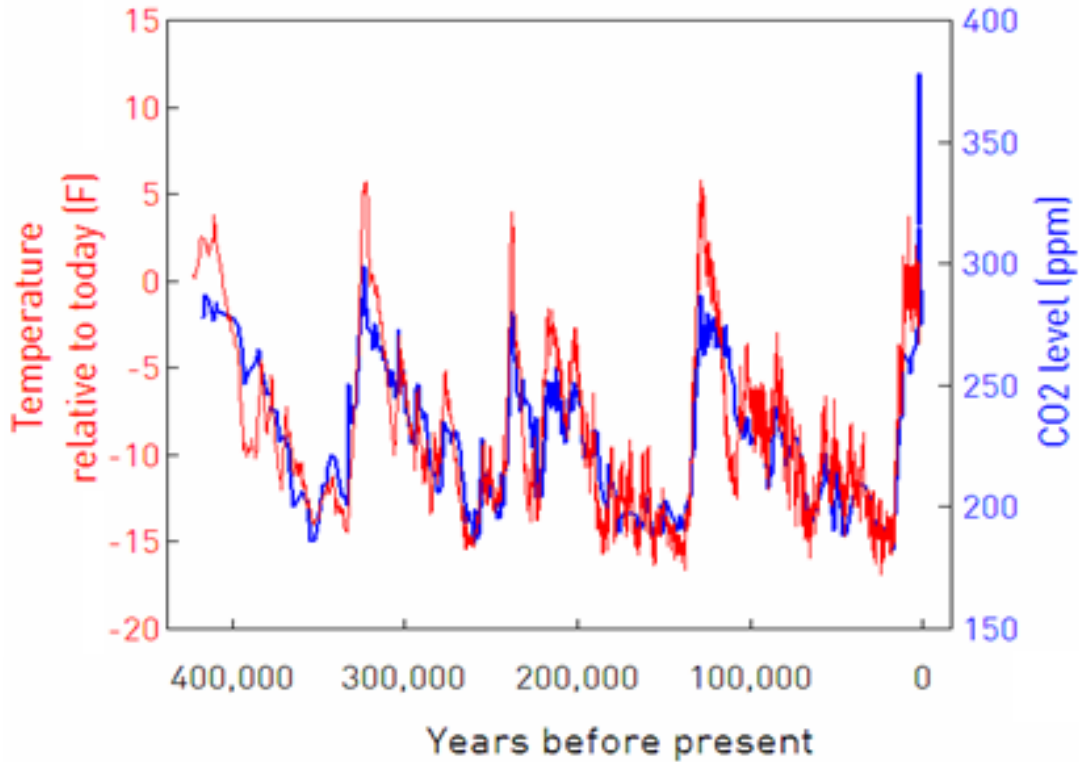
- A. Some heat is absorbed by greenhouse gases and then radiated to space
- B. Some heat makes its way to space directly
- C. Some heat is absorbed by greenhouse gases and is then radiated back towards the Earth's surface

With more carbon dioxide in the atmosphere later this century, more heat will be stopped by greenhouse gases, warming the planet

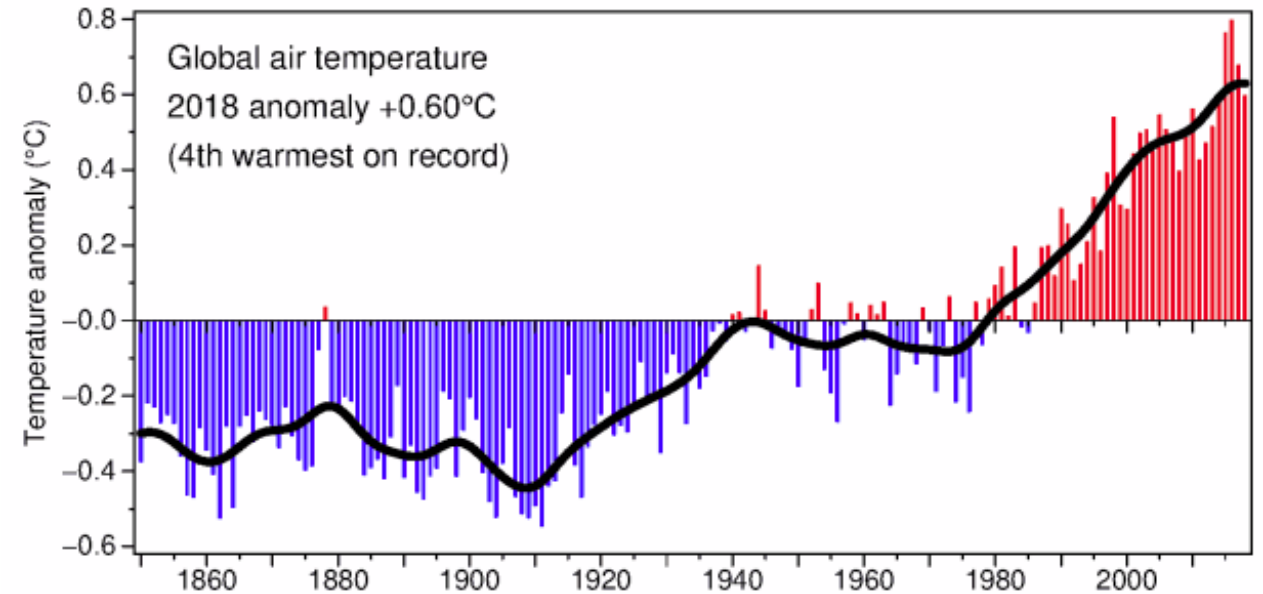


Greenhouse Gases Cause the Greenhouse Effect

Temperature and CO2 for Last 400,000 Years



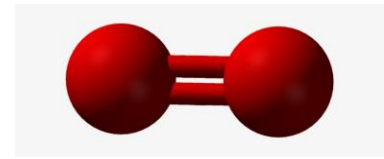
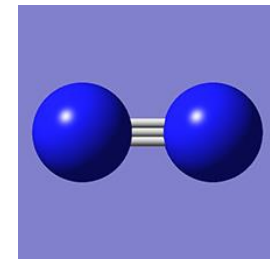
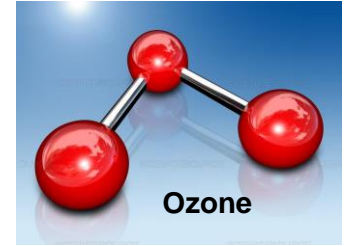
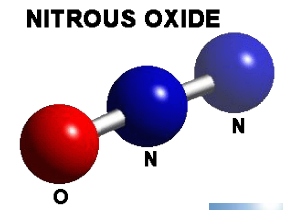
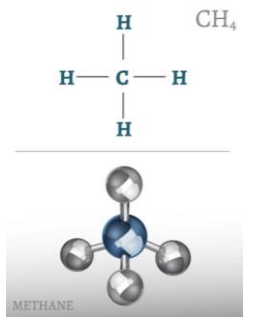
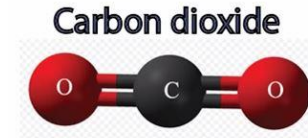
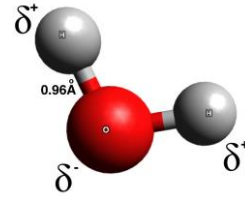
Vostok ice core data



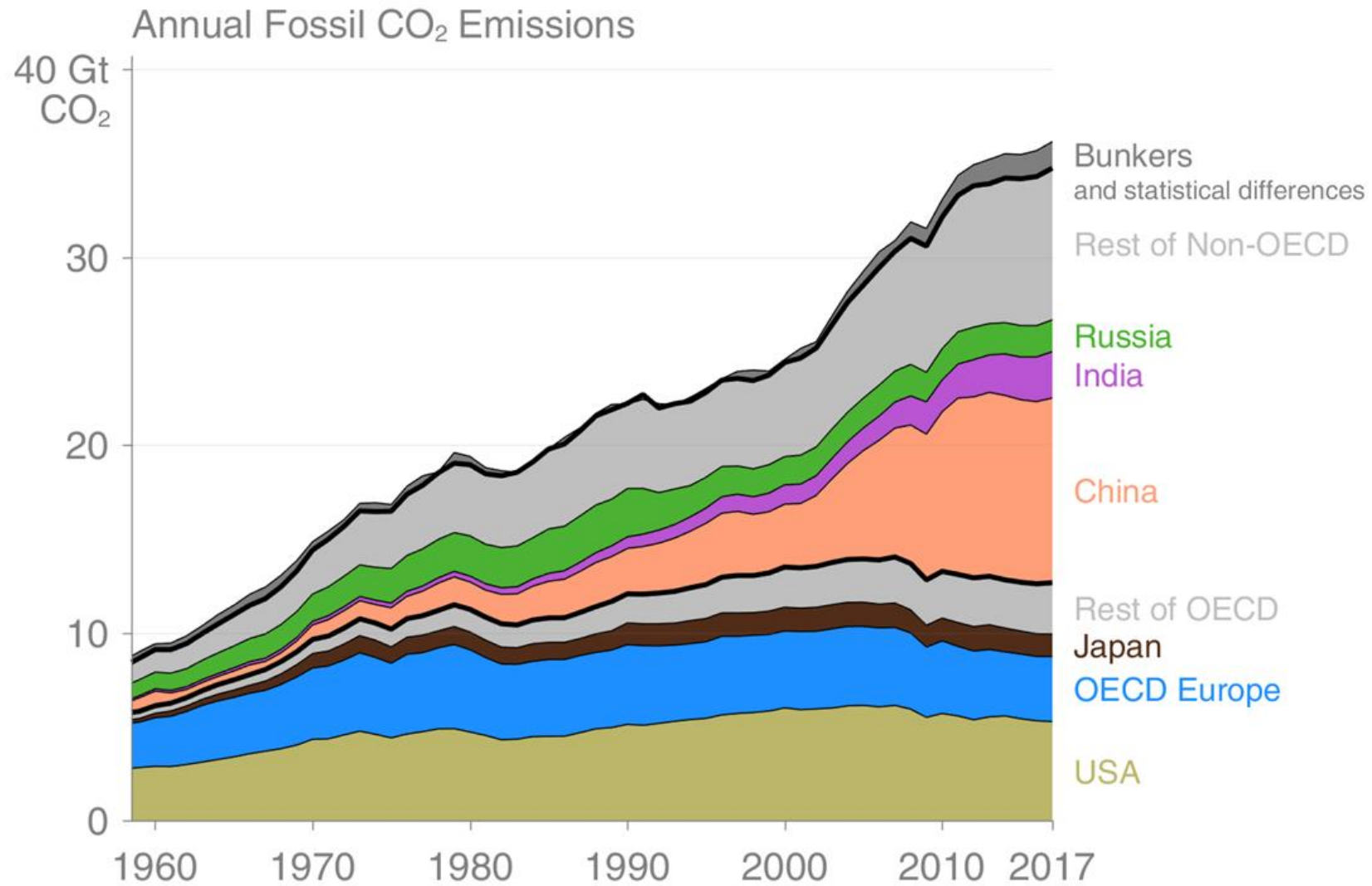
How do Greenhouse Gases Work?

- ❑ The major GHGs are **water vapor**, **carbon dioxide**, **methane**, **nitrous oxide** and **ozone**
- ❑ These gas molecules all are made of three or more atoms which are held loosely and can vibrate when they absorb heat
- ❑ Eventually, the vibrating molecules release the radiation, which will likely be absorbed by another greenhouse gas molecule
- ❑ This process keeps heat near the Earth's surface

- ❑ Most (99%) of the gas in the atmosphere is **nitrogen** and **oxygen** – both of which are molecules made of two atoms
- ❑ The atoms in these molecules are bound together tightly and unable to vibrate, so they cannot absorb heat and contribute to the greenhouse effect



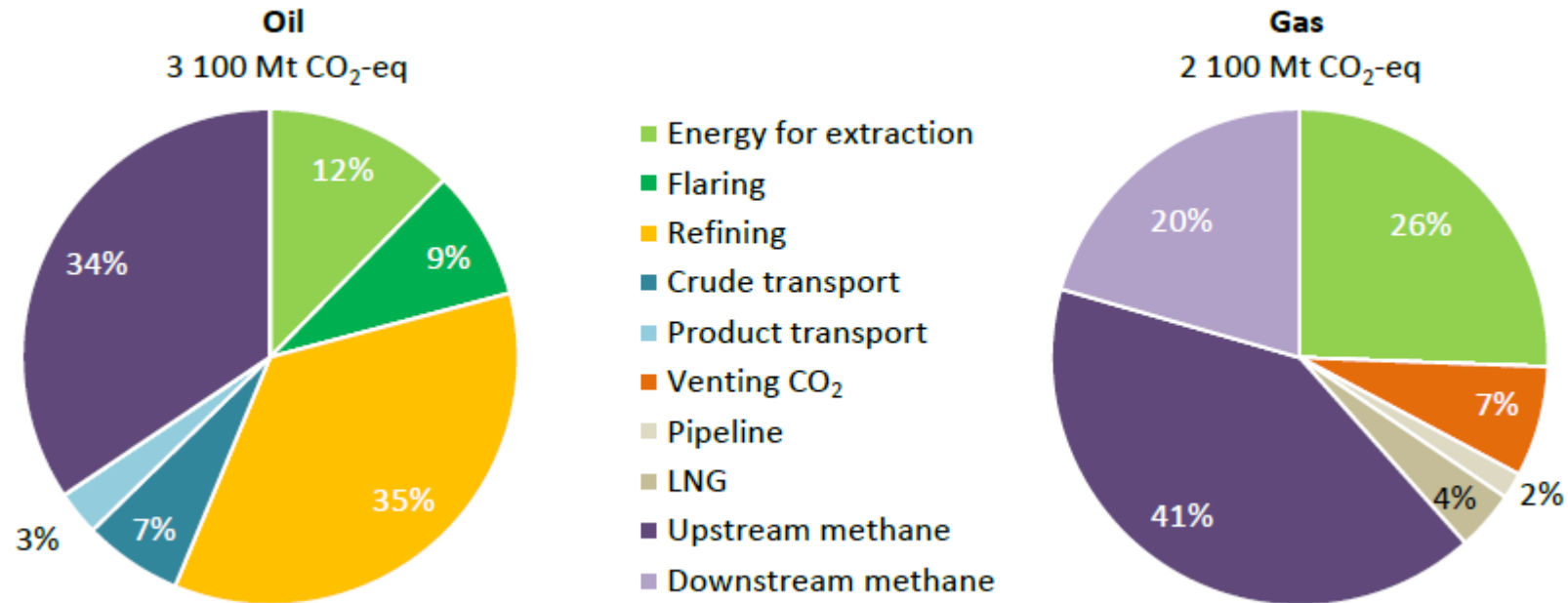
Sources of Global GHG Emissions



© Global Carbon Project • Data: CDIAC/UNFCCC/BP/USGS

Carbon Emissions of Oil and Gas

What are the GHG emissions associated with the supply (not use) of oil and gas?



“The **extraction, processing and transportation** of oil and gas is responsible for nearly **15%** of global energy sector GHG emissions today”

Carbon Pricing



<https://www.worldbank.org/en/news/feature/2016/06/29/a-look-at-carbon-pricing-and-competitiveness>

What is Carbon Pricing?

- ❑ Carbon pricing captures the **external costs** of greenhouse gas (GHG) emissions and ties them to their sources through a price, usually in the form of a price on the carbon dioxide (CO₂) emitted
 - The costs of emissions that the public pays for, such as damage to crops, health care costs from heat waves and droughts, and loss of property from flooding and sea level rise, etc.

- ❑ A price on carbon helps **shift the burden** for the damage from GHG emissions back to those who are responsible for it and who can avoid it

- ❑ Instead of dictating who should reduce emissions where and how, a carbon price **provides an economic signal** to emitters, and allows them to decide to either transform their activities and lower their emissions, or continue emitting and paying for their emissions

Carbon Pricing Mechanisms

- ❑ A **carbon tax** puts a direct price on GHG emissions and requires entities to pay for every ton of carbon pollution emitted
- ❑ An **emission trading system** (ETS)—also known as a cap-and-trade system—sets a limit (“cap”) on total direct GHG emissions from specific sectors and sets up a market where the rights to emit (in the form of carbon permits or allowances) are traded
- ❑ Under a **crediting mechanism**, emissions reductions that occur as a result of a project are assigned credits, which can then be bought or sold
- ❑ Under a **results-based climate finance** (RBCF) framework, entities receive funds when they meet pre-defined climate-related goals, such as emissions reductions
- ❑ Under **internal carbon pricing**, entities assign their own internal price to carbon use and factor this into their investment decisions

Carbon Policy & Regulations

Carbon pricing is the preferred method for an orderly energy transition

20% of global emissions are covered by carbon prices with an average carbon price = \$7 / tCO₂e

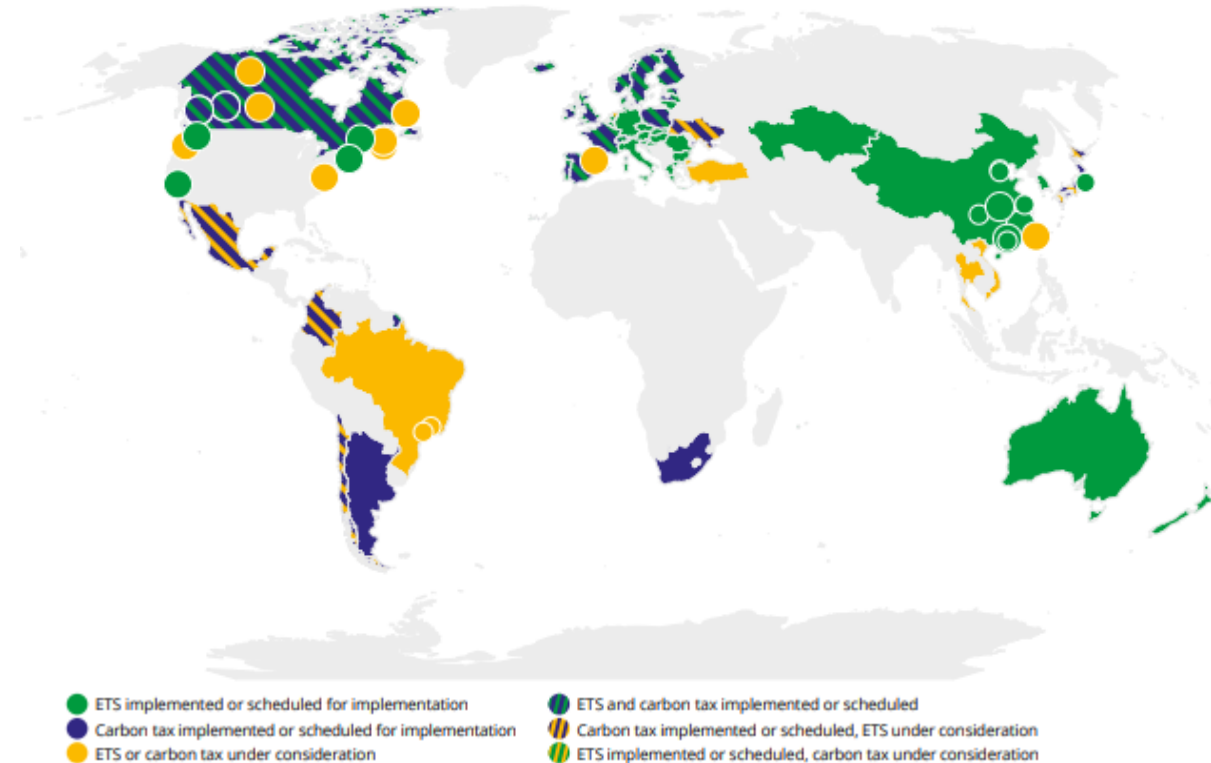
- Prices range from \$1 to \$139 / tCO₂e
- 46 national and 24 subnational jurisdictions covered

\$3 trillion has been spent on incentivizing renewable energy technologies

- Costs have dropped by 80%
- Over half of all new energy-generation capacity is now renewable

More capital is now spent on electricity than oil and gas supply

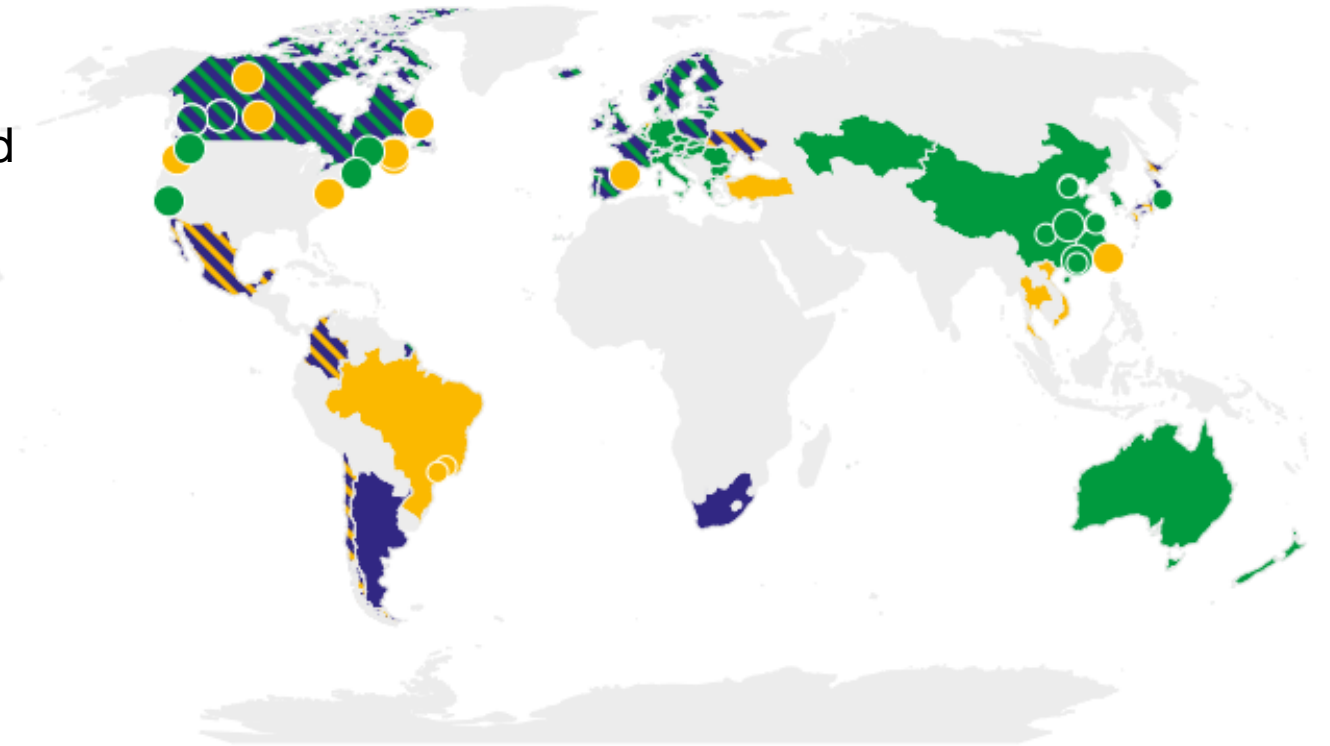
- Investment in electrification of transport and heating continues to grow



Potential Carbon Pricing Impact on Reserves

Purpose of Study

- ❑ Emissions regulations in the form of carbon pricing may soon become commonplace around the world
- ❑ In this carbon-conscious era, a price on carbon may well affect project economics in the oil and gas industry and would likely impact reserves estimates



● ETS implemented or scheduled for implementation

● Carbon tax implemented or scheduled for implementation

● ETS or carbon tax under consideration

● ETS and carbon tax implemented or scheduled

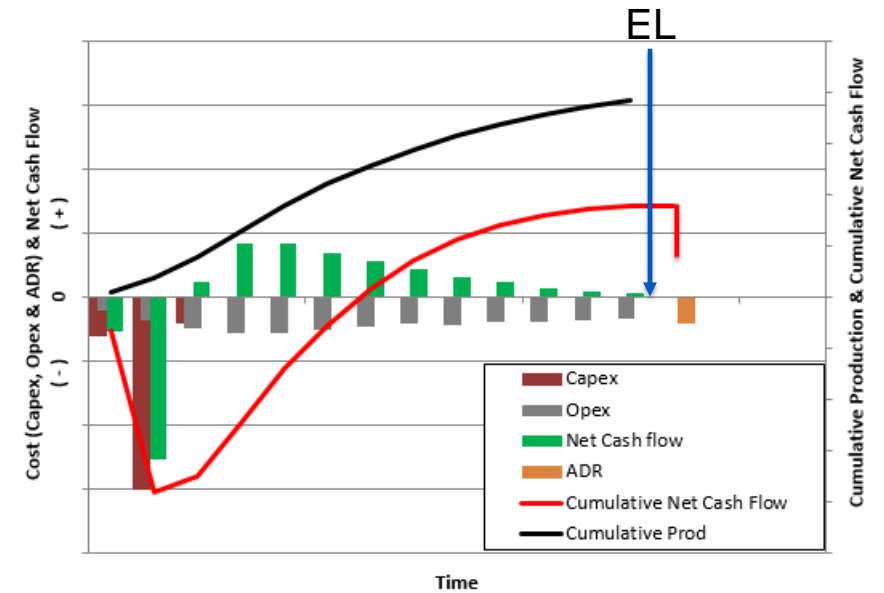
● Carbon tax implemented or scheduled, ETS under consideration

● ETS implemented or scheduled, carbon tax under consideration

ETS—emissions trading systems

Carbon Emissions Profile Modelling

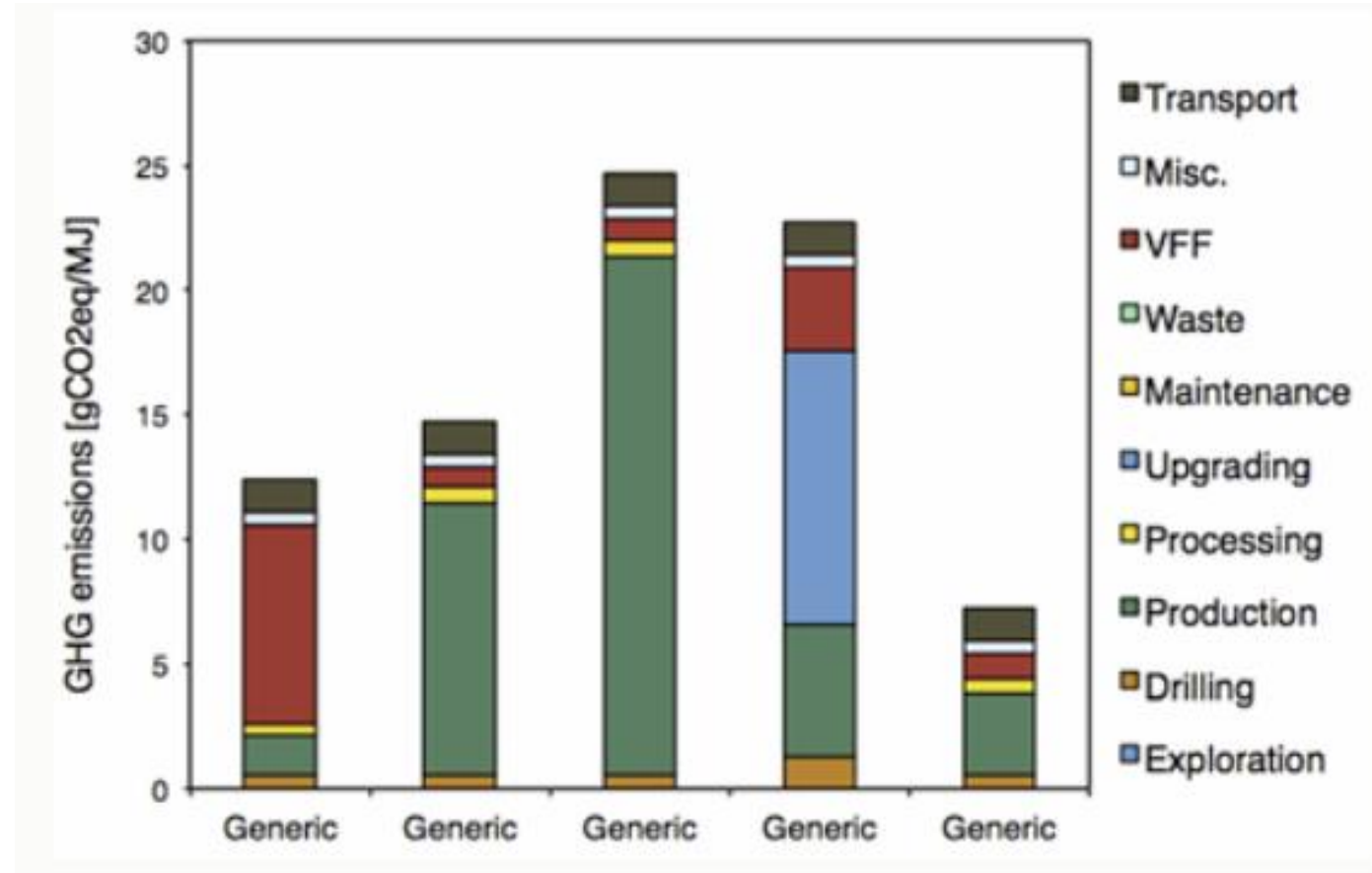
- ❑ The impact of carbon pricing can be assessed using normal cash flow techniques
- ❑ However, the big question is: “How much should it be?”
- ❑ There are two parts to the answer:
 - The amount of CO₂ equivalent that is released during a particular operation
 - The cost (or “price”) incurred as a result of those emissions
- ❑ To answer the first question, we used a public-domain program released by Stanford University to estimate the carbon emissions related to oil and gas operations
 - **Oil Production Greenhouse gas Emissions Estimator** (OPGEE) is designed to estimate lifecycle emissions based on a static description for a set of fields



Carbon Emissions Profile Modelling

The OPGEE program considers emissions from all parts of an oilfield's lifecycle (“wells-to-wheels”)

- Exploration
- Drilling
- Production
- Processing
- Upgrading
- Maintenance
- Waste
- VFF (vent, flare and fugitives)
- Miscellaneous
- Transport



- Selected production, processing and VFF
 - Ignored effects of exploration, drilling, transport, etc.

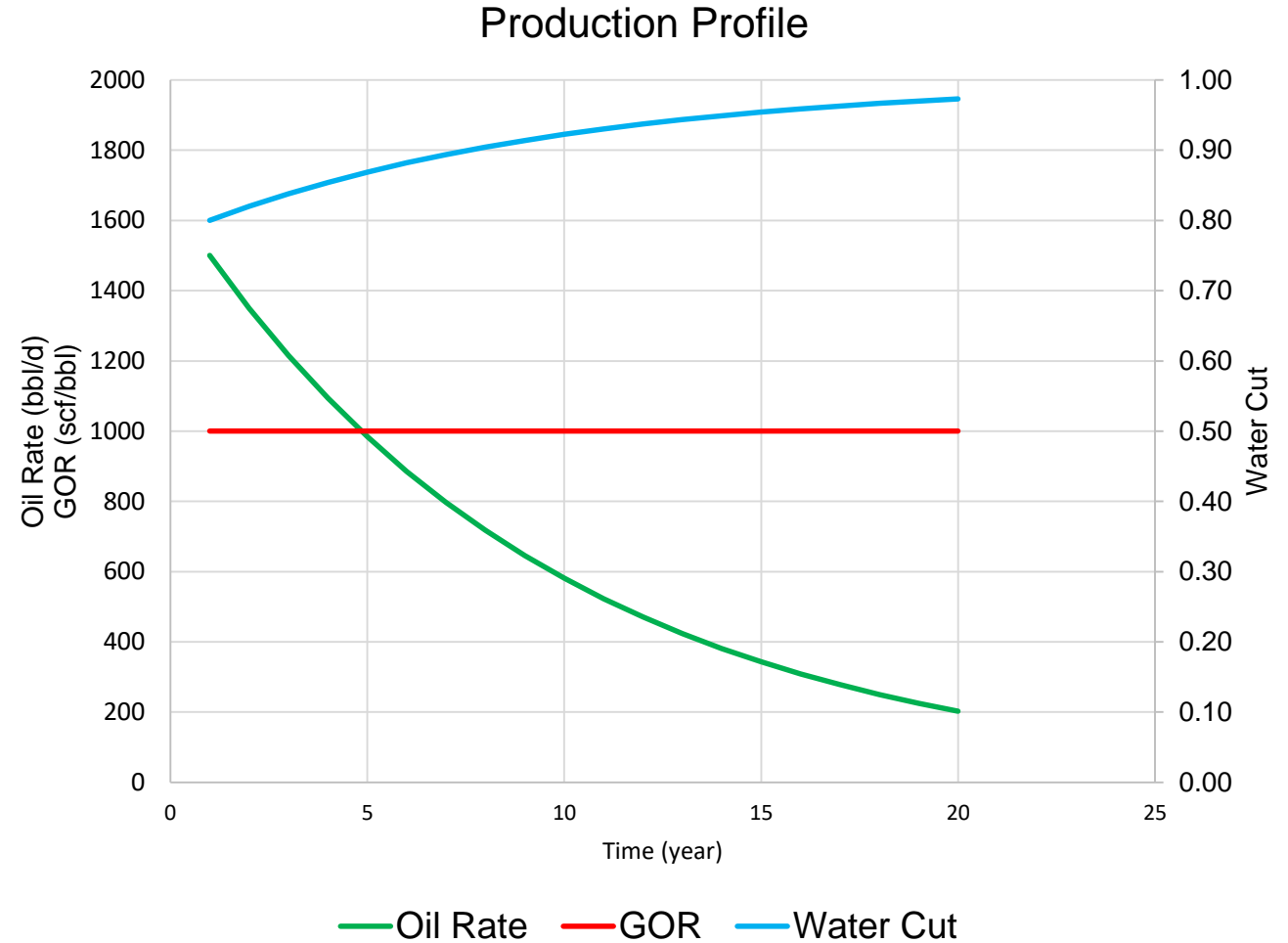
Carbon Emissions Profile Modelling—OPGEE

- ❑ The program is designed to consider life of field emissions for multiple fields
- ❑ Instead, program was modified to profile one field on a year-by-year basis
 - Used OPGEE model defaults for several parameters
- ❑ Resulting unit lifecycle CO₂e emissions were applied to the annual production volumes to create a carbon profile
- ❑ Prepared simple before-tax notional economic functionality to carry out economic limit test

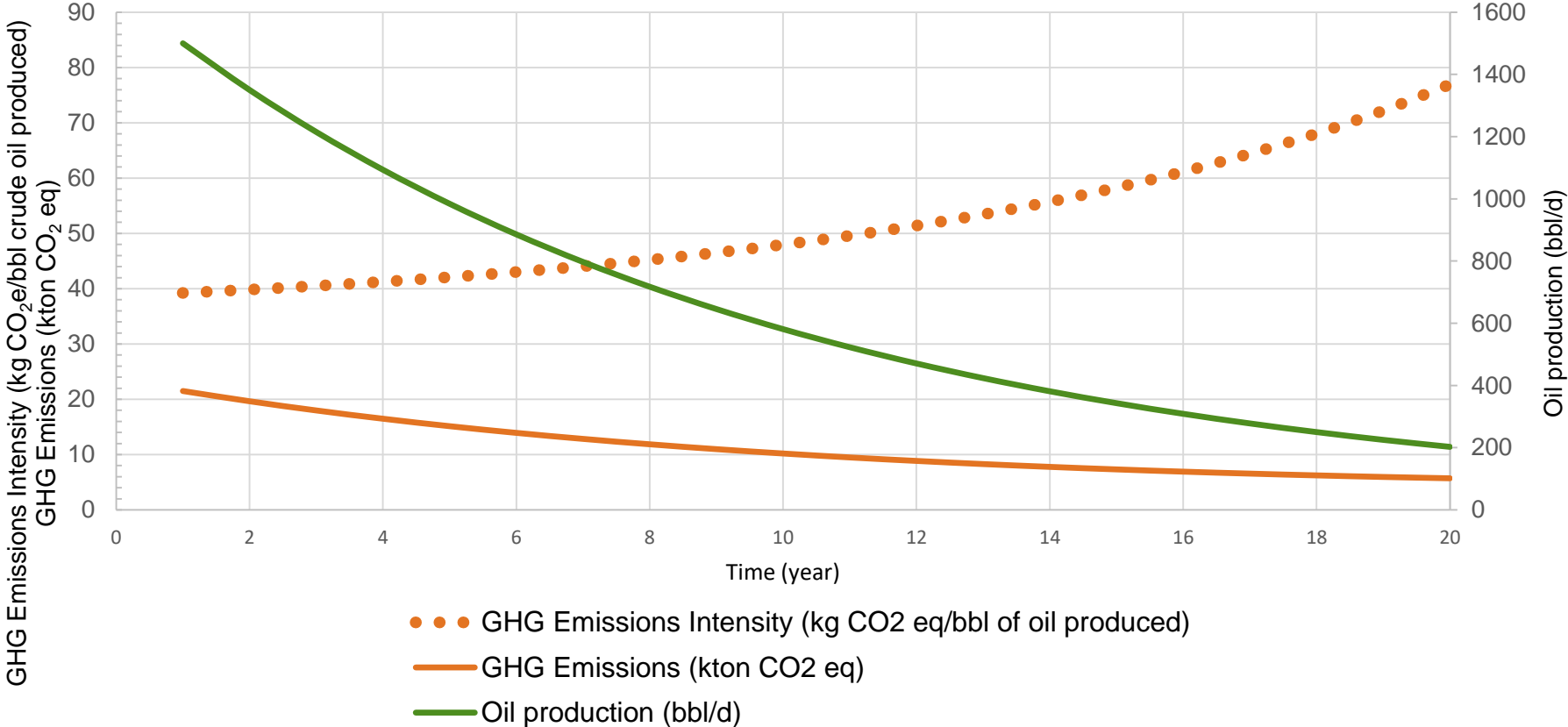
Note: we did not review the mechanics or assumptions of the OPGEE model

Oilfield Properties for Study

- ❑ Illustrative mature onshore oilfield in production decline
- ❑ Current oil rate 1,500 bopd
- ❑ Exponential decline at 10% per year
- ❑ Constant total liquid rate
- ❑ Water cut starts around 80%
- ❑ 8 producers and 5 water injectors (produced water reinjected)
- ❑ Constant GOR 1,000 scf/bbl
- ❑ Gas is flared at 200 scf/bbl (20% model default)
- ❑ Inputs for fluid properties, processing practices and others kept the same as model defaults



Emissions Profile



The increase in the emissions intensity over the 20 year span is attributed mainly to the production-related emissions at higher water cuts

Field Economics and Reserves

□ Prices

- Oil \$50/bbl
- Gas \$3/Mcf

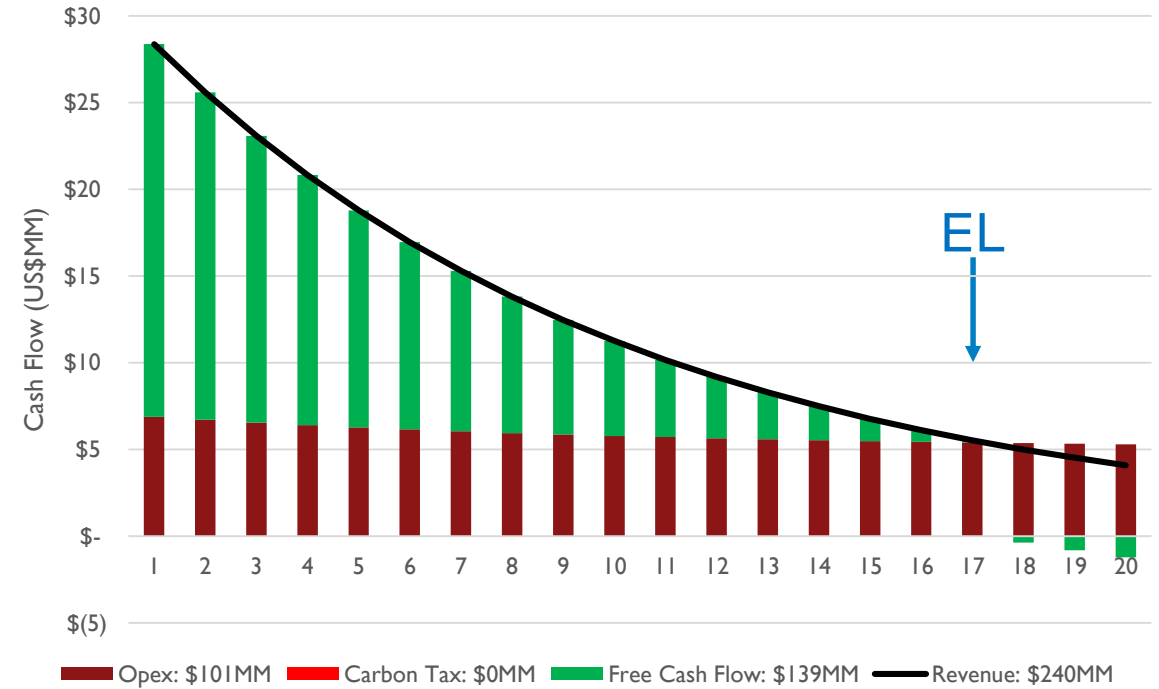
□ Simple cost assumptions

- Fixed opex \$5MM/year
- Variable opex \$3/boe

□ When no carbon tax is in place, the economic limit (EL) is reached in year 17 and reserves would be 4.6 MMbbl

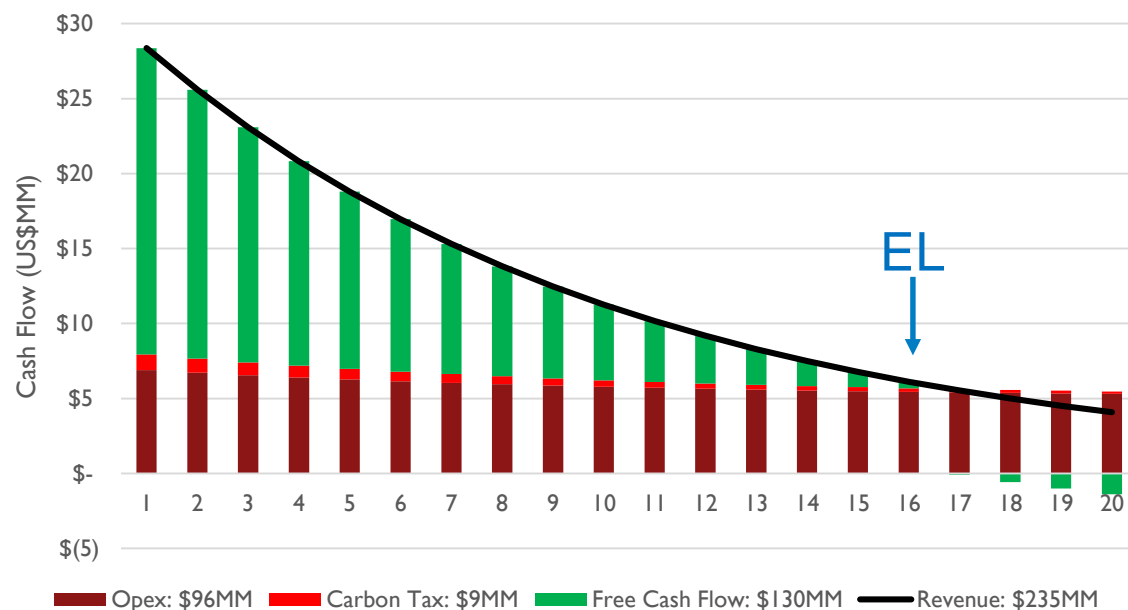
□ Carbon tax levels analyzed

- \$50/tonne CO₂e
- \$150/tonne CO₂e

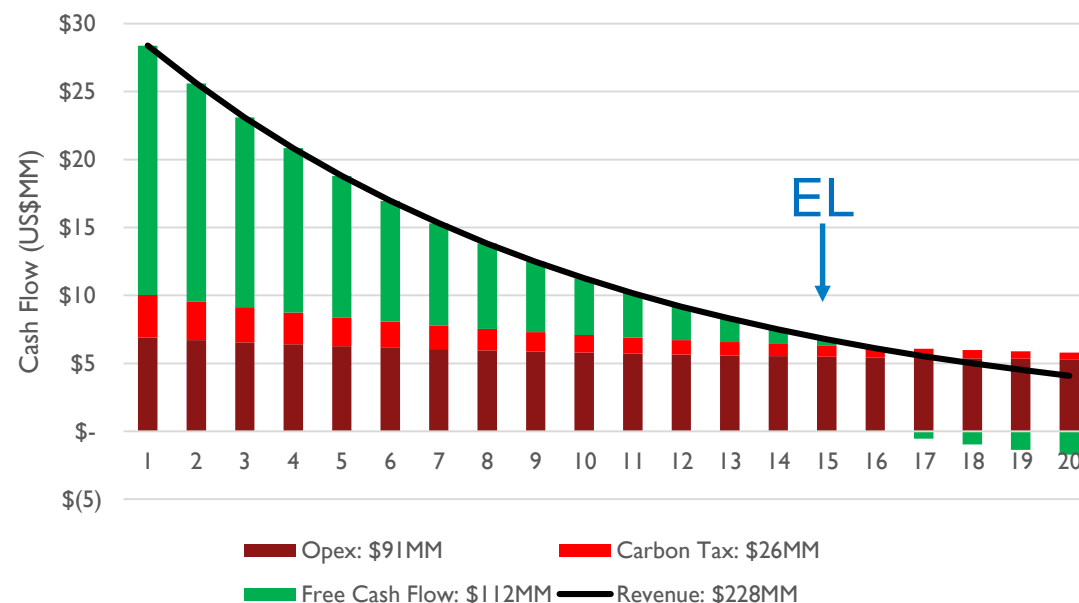


Field Economics and Reserves

At \$50/tCO₂e, production would stop in year 16 and reserves drop by 0.1 MMbbl



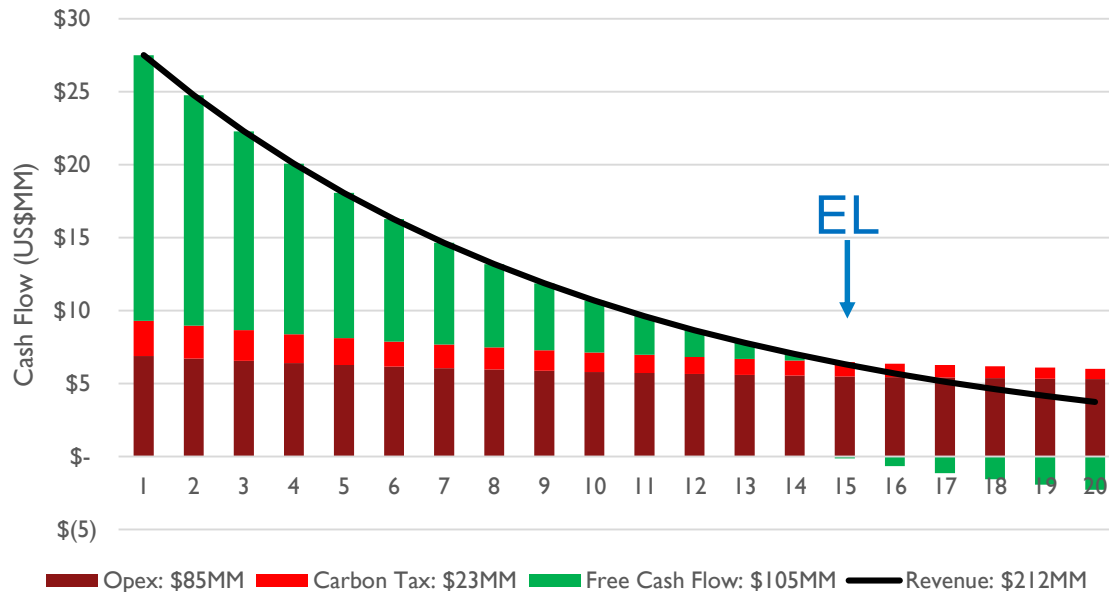
At \$150/tCO₂e, production would stop in year 15 and reserves drop by 0.4 MMbbl



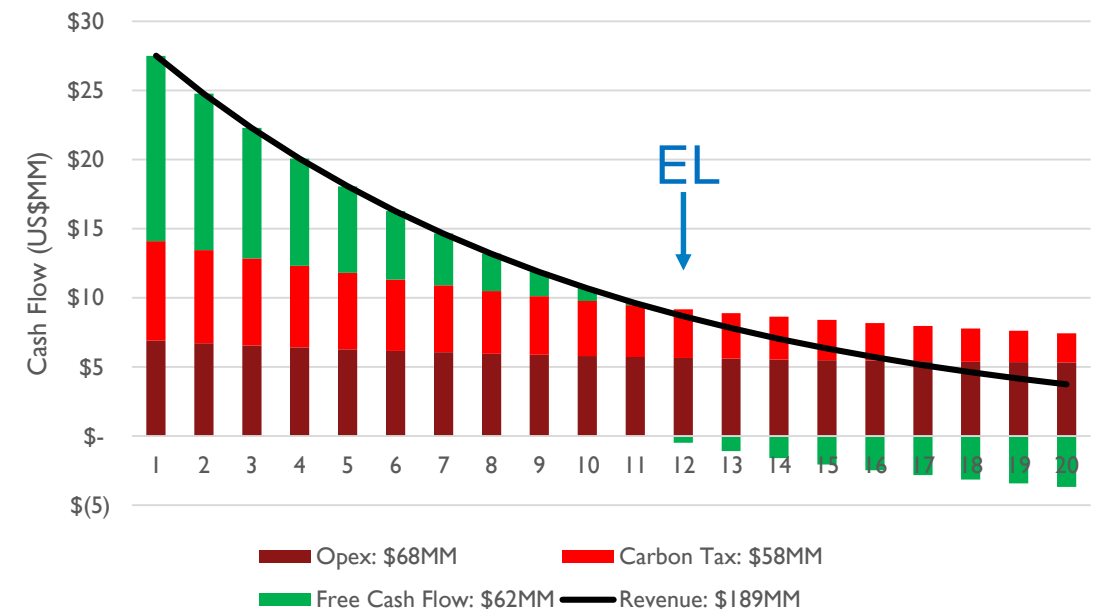
Flaring Sensitivity

Two additional cases (3 and 4) were run to illustrate the effect of flaring 90% of gas produced (instead of 20% as in prior case) on field economics

At \$50/tCO₂e, production would stop in year 15 and reserves drop by 0.4 MMbbl



At \$150/tCO₂e, production would stop in year 12 and reserves drop by 0.7 MMbbl



Summary of Cases and Resulting Reserves and Cash Flows

Case	Annual Flare (MMscf)	Carbon Tax (US\$/tCO ₂ e)	EL Year	Reserves (MMbbl)	Reserves Drop %	Cum. CF (US\$MM)	NPV10% (US\$MM)
Base	44	-	17	4.6	-	139	93
1	44	50	16	4.5	2%	130	87
2	44	150	15	4.2	9%	112	75
3	276	50	15	4.2	9%	105	74
4	276	150	12	3.9	15%	62	48

Mitigation Technologies

❑ Avoid emissions

- Eliminate flaring, venting & fugitives through produced gas re-injection/conversion, alternative valve actuators, surveillance, etc.

❑ Reduce inefficiency

- Increase energy efficiency design of pumps/compressors/heaters, cogeneration of power and heat, improve flare tip/system design, increase electrification

❑ Replace with alternatives

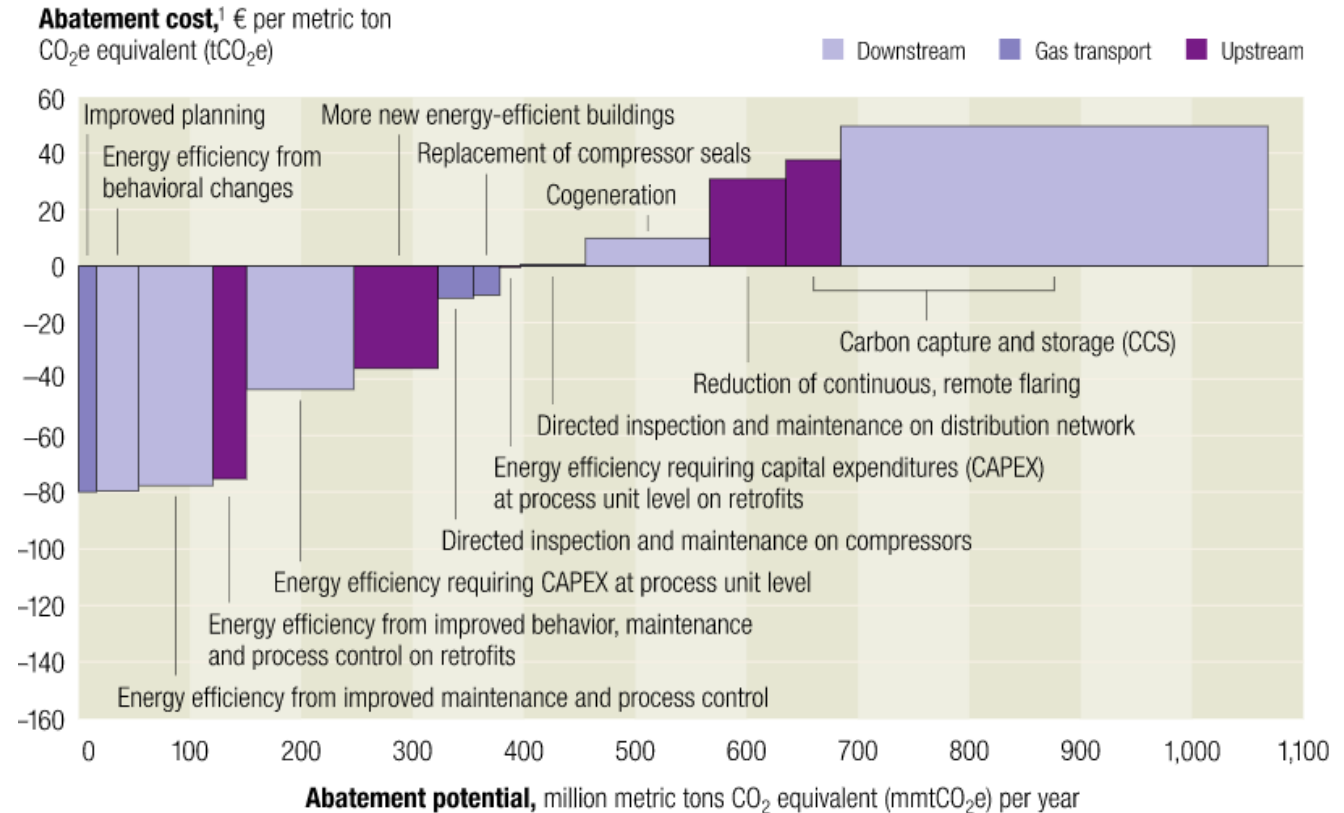
- Integrate low carbon options such as renewables (biomass, wind and solar)

❑ Offset elsewhere

- Reforestation, land-use protection, farming practices, renewable energy

❑ Sequester captured CO₂

- Carbon capture, use and storage (CCUS)



What Companies are Doing

- ❑ **Exxon Mobil Corp.** is putting \$1 million into a political campaign that, if successful, would effectively spawn a tax tied to the company's core products
 - <https://www.bloomberg.com/news/articles/2018-10-09/exxon-puts-1-million-into-quest-for-carbon-tax-and-rebate-plan>

- ❑ **Royal Dutch Shell's** support for carbon pricing models is a sign that the company is ready to make climate change concessions, according to environmental experts
 - <https://www.cbc.ca/radio/day6/shell-backs-a-carbon-tax-amsterdam-benefits-from-brexit-veep-s-jonah-ryan-canada-s-dwindling-caribou-more-1.5084280/shell-s-support-for-a-carbon-tax-is-environmentally-conscious-and-financially-savvy-says-researcher-1.5084295>

- ❑ **Shell Oil** Quietly Urges Lawmakers to Support Carbon Tax
 - The company sees carbon pricing as an essential policy tool to tackle climate change
 - <https://www.scientificamerican.com/article/shell-oil-quietly-urges-lawmakers-to-support-carbon-tax/>

- ❑ **Exclusive: Oil giant ConocoPhillips** backs carbon tax push
 - <https://www.axios.com/conocophillips-backs-carbon-tax-push-a0c47c65-7a0e-4ec6-85c6-771687849a97.html>

- ❑ **BP** Says Some of Its Oil 'Won't See the Light of Day'
 - <https://www.bloomberg.com/news/articles/2019-07-02/bp-says-some-of-its-oil-won-t-see-the-light-of-day>

Conclusions

- ❑ 20% of worldwide production covered by current carbon pricing
- ❑ It may not be long before implementation is global
- ❑ There will be an impact on reserves and resources estimates
- ❑ As evaluators, we must be ready
- ❑ PS: our meals today probably “cost” 3-4 kg CO₂ each, equivalent to driving your car 10 miles

Thank You

Questions?