CARBON LIMITS

Best Available Techniques Economically Achievable to address black carbon from gas flaring

A report prepared by Carbon Limits as one of the deliverables under the project EU Action – Black Carbon in the Arctic, funded by the European Union

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BATEA to address BC From Gas Flaring

REPORT OVERVIEW

- Provides technical guidance on possible black carbon abatement measures where associated gas is flared during oil extraction activities
- Updated and complete overview of existing options, addressed both to national administrations and businesses
- Intended users could include oil & gas field operators (and owners), investors or other decision-makers
- Can also assist national administrators contemplating enhanced environmental legislation regarding BC emission reductions from flaring
- Other stakeholders involved in or affected by oil and gas operations in the Arctic.

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REPORT OVERVIEW

- Hydrocarbon operations involve the separation and processing of reservoir fluid combinations of gas, oil and water (along with various other constituents)
- Systems used for this purpose incorporate flaring capability to release gases to the atmosphere (flaring specifically describes the situation in which gas is combusted upon its release via a flare header)
- Flaring recognized as a significant source of GHG emission and air pollution in the Arctic, for which risks must be managed accordingly!

Emissions from Flaring include:

- Carbon dioxide (CO_2)
- Carbon monoxide (CO)
- Methane (CH_4) & VOCs
- Sulphur oxides (SO_x)
- Nitrogen oxides (NO_x)
- Particles (black carbon, soot)

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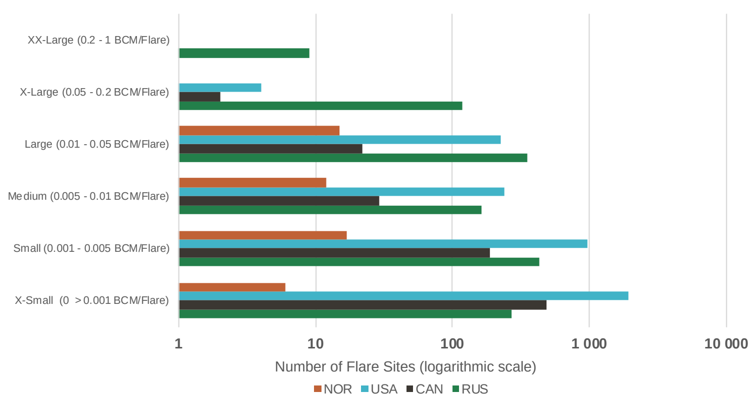
REPORT OVERVIEW

Number of nation-wide APG flares (Arctic Countries)



NOAA Flaring estimates produced by Satellite observations (VIIRS technology), 2016 data

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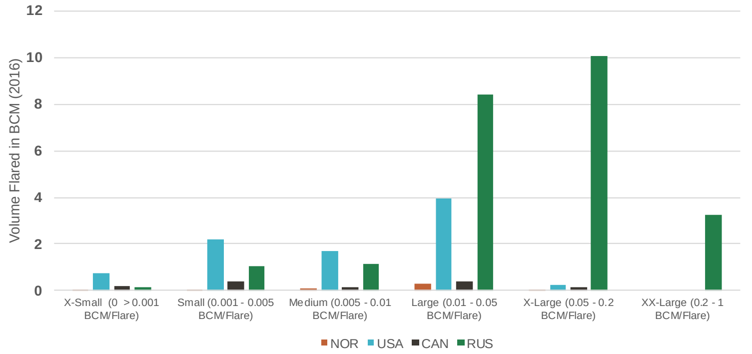
REPORT OVERVIEW

Volume of nation-wide APG flares (Arctic Countries)



*NOAA Flaring estimates produced by Satellite observations (VIIRS technology), 2016 data

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BATEA to address BC From Gas Flaring
REPORT OVERVIEW

The report consists of 3 main sections in addition to the introduction:

1. Flare characteristics are highlighted including a presentation of categorization, relevance of gas composition, available volumes over time and the importance of geographical diversity of fields;
2. Each BATEA is described with a summary page presenting the key information, followed by a more detailed description provides additional insights;
3. A summary table of a review performed on existing technical guidance documents and related national legislation, highlighting some of the limitations of existing guidance documents with respect to emissions of black carbon from gas flaring.

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REPORT OVERVIEW

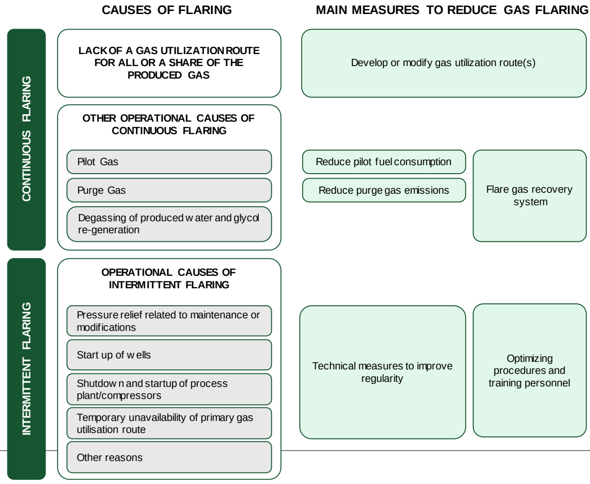
1st section: FLARE CHARACTERISTICS

Majority of flaring…

- caused by lack of market outlets
- shortage of local demand
- technical constraints
- poor economics

Minority of flaring…

- exploration flaring
- process flaring
- emergency flaring



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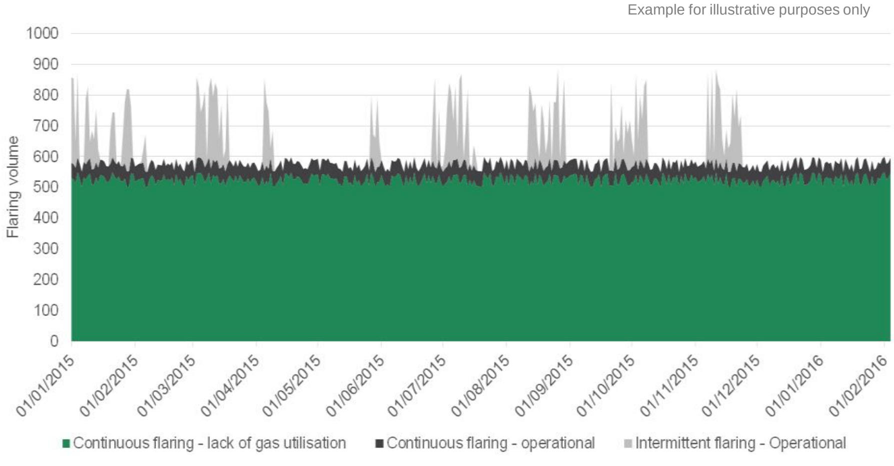
REPORT OVERVIEW

Example for illustrative purposes only



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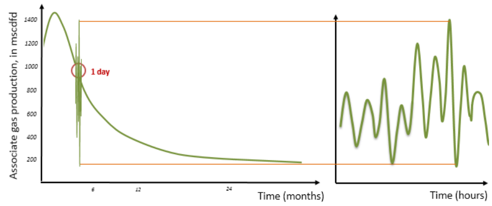
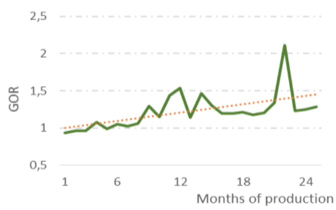
REPORT OVERVIEW

Associated gas utilization: Technical and geographical challenges

KEY CHALLENGES FOR GAS UTILISATION

- Production decline rate
- Short term volume variation
- Low pressure of the gas
- Distance from infrastructure
- Gas composition & quality
- Gas-Oil-Ratio (GOR) over time





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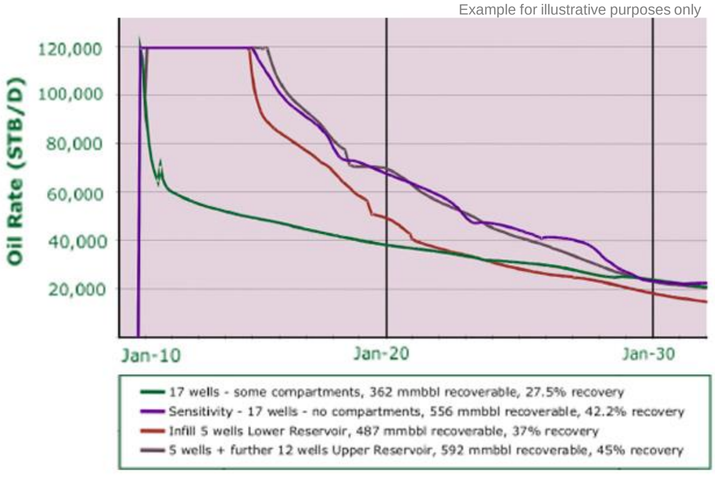
Sizing APG recovery technologies

Decline curve considerations

Example for illustrative purposes only



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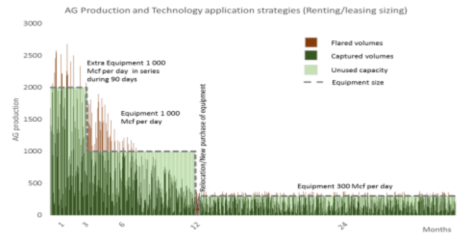
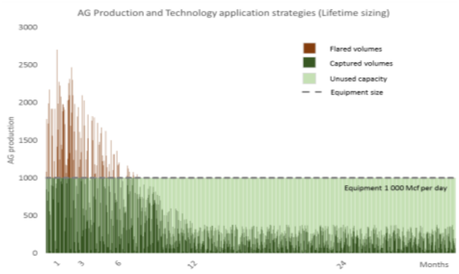
REPORT OVERVIEW

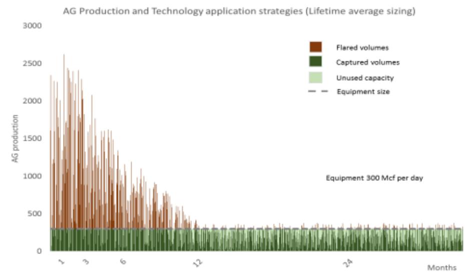
Sizing APG recovery technologies: Gas utilization rates, remaining field life, technology scaling

Considerations:

- Lifetime sizing
- Lifetime average sizing
- Renting/leasing/flexible sizing







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REPORT OVERVIEW

Gas composition challenges:

Example for illustrative purposes only

APG Composition (Mole %)		Field A	Field B	Field C	Field D
Carbon dioxide (CO_2)		1.15 %	3.76 %	1.32 %	0.49 %
Methane (CH_4)		73.57 %	79.65 %	49.90 %	60.37 %
Ethane (C_2H_6)		9.32 %	7.26 %	15.31 %	2.39 %
Propane (C_3H_8)		9.27 %	5.31 %	19.40 %	9.26 %
Butane (C_4H_{10})		4.44 %	2.69 %	9.24 %	14.17 %
Pentanes (C_5H_{12})		1.34 %	0.56 %	2.05 %	10.11 %
Hexanes (C_6H_{14})		0.18 %	0.09 %	0.26 %	0.00 %
Heptanes (C_7H_{16})		0.00 %	0.00 %	0.08 %	0.00 %
Octanes + (C_8H_{18})		0.00 %	0.00 %	0.01 %	0.00 %
Nitrogen (N)		0.77 %	0.57 %	2.44 %	2.55 %
Water (H_2O)		0.00 %	0.00 %	0.00 %	0.00 %
Oxygen (O)		0.00 %	0.00 %	0.00 %	0.65 %
Hydrogen Sulfide (H_2S)		0.00 %	0.11 %	0.00 %	0.00 %
Net Calorific Value:	(BTU/SCF)	1224.96	1071.47	1519.50	1612.59
	(MJ/SCM)	45.55	39.85	56.51	59.97

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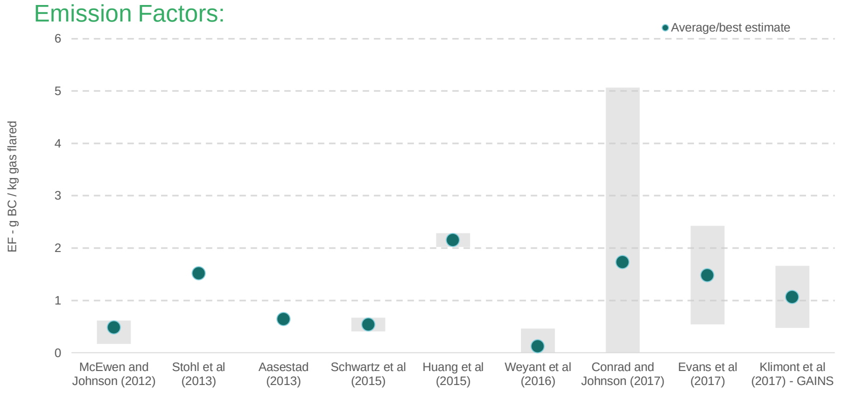
REPORT OVERVIEW

Emission Factors:



APPROACH	Laboratory	Top - down	McEwen formula	Aircraft Sampling	McEwen formula	Aircraft Sampling	Sky - LOSA	Literature	Literature
LOCATION	Canada	NA	Norway	North Dakota	Russia	North Dakota	Ecuador	Russia	Global

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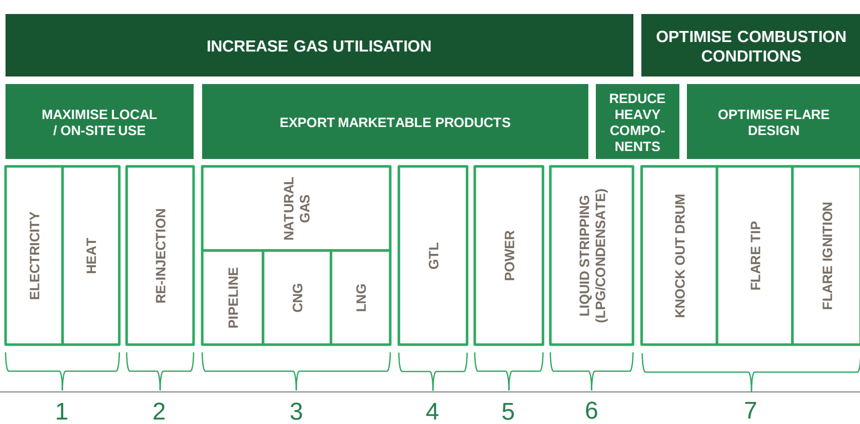
BEST PRACTICE FOR BC FROM GAS FLARING

OVERVIEW

Abatement measures identified have been described across 7 broader Best Available Techniques Economically Achievable (BATEA) and can be considered particularly relevant towards demonstration and feasibility projects in the Arctic Regions



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BATEA to address BC From Gas Flaring

REPORT OVERVIEW

BAT Overviews: “1-Page-Boxes”

- Technology summary
- Applicability to the Arctic
- Effect on emissions
- Benefits
- Infrastructure requirements
- Technical & economic considerations
- Visual overview
- Links to further information

BAT: Detailed information section

- Detailed technology descriptions
- Detailed investment considerations

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BATEA to address BC From Gas Flaring

REPORT OVERVIEW – SUMMARY BOX STRUCTURE

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BATEA 2: Maximize On-Site Use – Re-injection

Effect on Emissions

- Significantly reduces emissions of:
  - CO_2
  - PM (incl. BC)
  - SO_x
  - Heavy metals
- Project emissions, including CO_2, are created from combusting gas (e.g.: compressors are required to reinject)

Benefits

- Re-injection into the same reservoir can, in some cases, provide enhanced oil recovery (EOR) in mature fields
- EOR could significantly increase oil production (economic benefits)
- Storage of gas in other reservoirs could provide long-term storage of a large fraction of injected gas (for future production) or provide for short-term swing capacity

Summary

Associated gas is recovered from the flare stack and re-injected into a reservoir for:

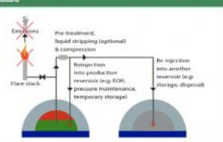
- Enhanced Oil Recovery (EOR) / pressure maintenance
- Temporary or permanent storage - APG can be reinjected into existing or other suitable - typically depleted - reservoirs within the area / close proximity

Applicability (to the Arctic):

- Mature oil fields in remote areas far from utilization infrastructure (e.g.: pipelines, gas processing plants, electricity grids)
- Fields that have been identified in close proximity to depleted reservoirs or other suitable formations for re-injection (e.g.: salt caverns)
- EOR through re-injection could carry benefits such as increased or prolonged oil production in mature fields
- For temporary injection - Arctic fields where future gas utilization or product conversion projects are in development close by (e.g.: GTL, LNG) or where recovery and export could become economically viable in future

Infrastructure Requirements

- Gas pre-processing & conditioning equipment
- Optional NGL separation equipment (**BATEA 6**)
- High-capacity compressors
- Injection wells (former production wells may be adapted to save cost)
- Piping & related infrastructure (particularly in consideration of gas transportation and injection at another site)
- Reservoir management & monitoring systems (especially for EOR schemes)



General Technical & Economic Considerations

- Compositional constraints and requirements for gas conditioning (e.g.: H_2S content) before compression and reinjection activities can commence
- Viability of separating NGLs from APG (see **BATEA 6**) and re-injecting only NG gas (depending on economic value)
- Implementing only a partial re-injection scheme and utilizing remainder, e.g. on-site use (see **BATEA 1**)
- General high capital cost of infrastructure, particularly depth of target reservoir and complexity of wells (cost estimation consideration).
- Volume of APG required to be injected considering other more economical solutions to avoid flaring (costs vs. returns from EOR or speculative value of preserving gas for future use need to be considered)
- Geographical location of field (costs offshore are significantly higher than onshore).
- Gas compression cost for re-injection activities (some gas will conceivably be used as fuel)

Particular Considerations for EOR

- Reservoir geology and configuration (e.g.: miscibility - compatibility with reservoir fluids, capacity - available volumes, injectivity - reservoir pressure limitations)
- ROI for EOR schemes (high uncertainties regarding efficiency and added oil for recovery)
- Gas injection under an EOR scheme has to economically compete with other alternatives for gas utilization (e.g.: availability and distance of gas gathering pipelines should be examined)
- Management and monitoring system requirements (regular reservoir behaviour evaluation requirements) to analyze gas performance and movement towards producer wells (potential gas-cycling issues) in oil reservoirs.

Particular Considerations for Storage & Disposal

- Economic drivers for disposal (only environmental considering unless savings in flare fines)
- Main economic driver for temporary storage schemes (e.g.: better utilization of transportation systems, improved delivery

BATEA 7: Optimize Combustion Conditions – Advanced Flare Design

Effect on Emissions

- Depending on design parameters, can reduce emissions of:
  - PM (incl. BC)
  - CH_4 and non-methane VOCs
  - Other Hazardous pollutants
- Depending on design parameters may conversely increase other emissions such as CO_2 or NO_x

Benefits

- Provides technical alternatives to more environmentally friendly flaring practices
- Reducing (otherwise burned) heavier hydrocarbons can provide for a valuable resource

Summary

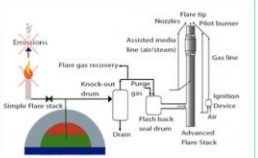
Associated gas is recovered from the conventional flare stack and sent to an appropriately sized and well-maintained knock-out drum to remove heavier hydrocarbons from the flare stream and sent to an improved flare stack where it is combusted using advanced flare tip and flare ignition technology

Applicability (to the Arctic):

- Remote areas where there is no feasible technical or economic possibility for the recovery of APG for any other purpose
- In relevant circumstances (depending on the flare compositions) air-assisted flares could represent a good alternative option to steam assisted flare for Arctic conditions freezing weather conditions can sometimes cause the steam in steam assisted flares to condense and freeze, plugging up the flare tip (in this case, it is common to turn off the center steam and increase the purge gas flow rate)

Infrastructure requirements:

- Knock-out drum (to retrieve hydrocarbon liquids)
- Flash back seal drum (with consideration for equipment to reduce the need for purge gas)
- Advanced Flare Designs
  - Pressure-assisted
  - Air-assisted
  - Steam-assisted
  - Sonic
  - Multi-tips
  - Staged
  - Enclosed
- Advanced Ignition system (manual/automatic pilot, ballistic)
- Measurement and control systems (e.g.: for ignition and monitoring pilot burners)



Main Technical & Economic Considerations

- The primary objective of a flare is to dispose safely of the associated gas (design will need to also address safety, environmental and social requirements)
- Technologies can aid in achieving smokeless operation and high combustion efficiency (< 2% unburned hydrocarbons) when properly sized, maintained and operated, however poor design or poor maintenance can lead to smoke formation or high inefficiency (> 30% unburned hydrocarbons)
- Appropriate flare selection (and specific emissions released from a gas flare) depend on various parameters, in particular gas flare rate & gas composition & pressure. The design should consider the full range of flare operating conditions.
- Ambient conditions (e.g.: wind, temperature) need to be appropriately considered when selecting technology
- Design and maintenance of a knockout drum will impact the black carbon emissions from a flare (if not sized or maintained properly, liquids droplets may be entrained by a waste gas stream and be burned incompletely resulting in smoke formation. Micro condensation units for knock-out drums can be considered an effective black carbon emissions reduction option
- Choices will depend on the utility costs and availability (have implications for equipment, installation & maintenance costs)
- Consideration also needs to be given to the technology applicability (onshore/offshore) and that no economic benefit can be considered from implementing this BATEA
- This BATEA should be considered also for reducing BC emissions from non-routine flaring

Links to Further Information

- Flare gas design for efficient control & operation: https://www.flowcontrolnetwork.com/flare-gas-system-design-for-efficient-control-and-operation/
- Flare systems – Design alternatives, components key to optimum flares: https://www.ogj.com/articles/print/volume-90/issue-47/in-this-issue/refining/flare-systems-1-design-alternatives-components-key-to-optimum-flares.html

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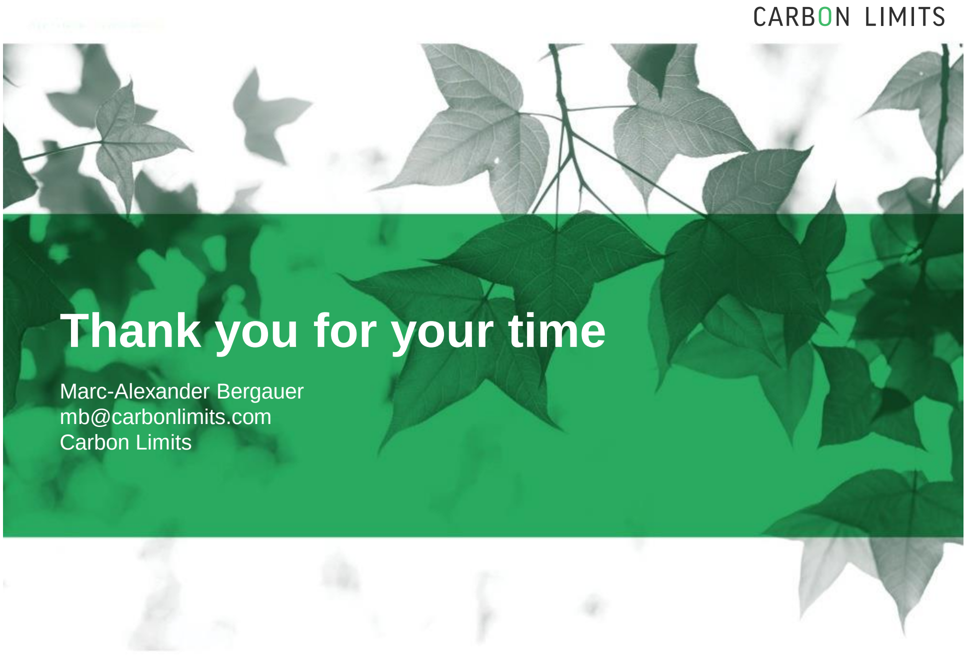
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