Oil and Gas Methane Emissions Mitigation – Opportunities and Costs in North America

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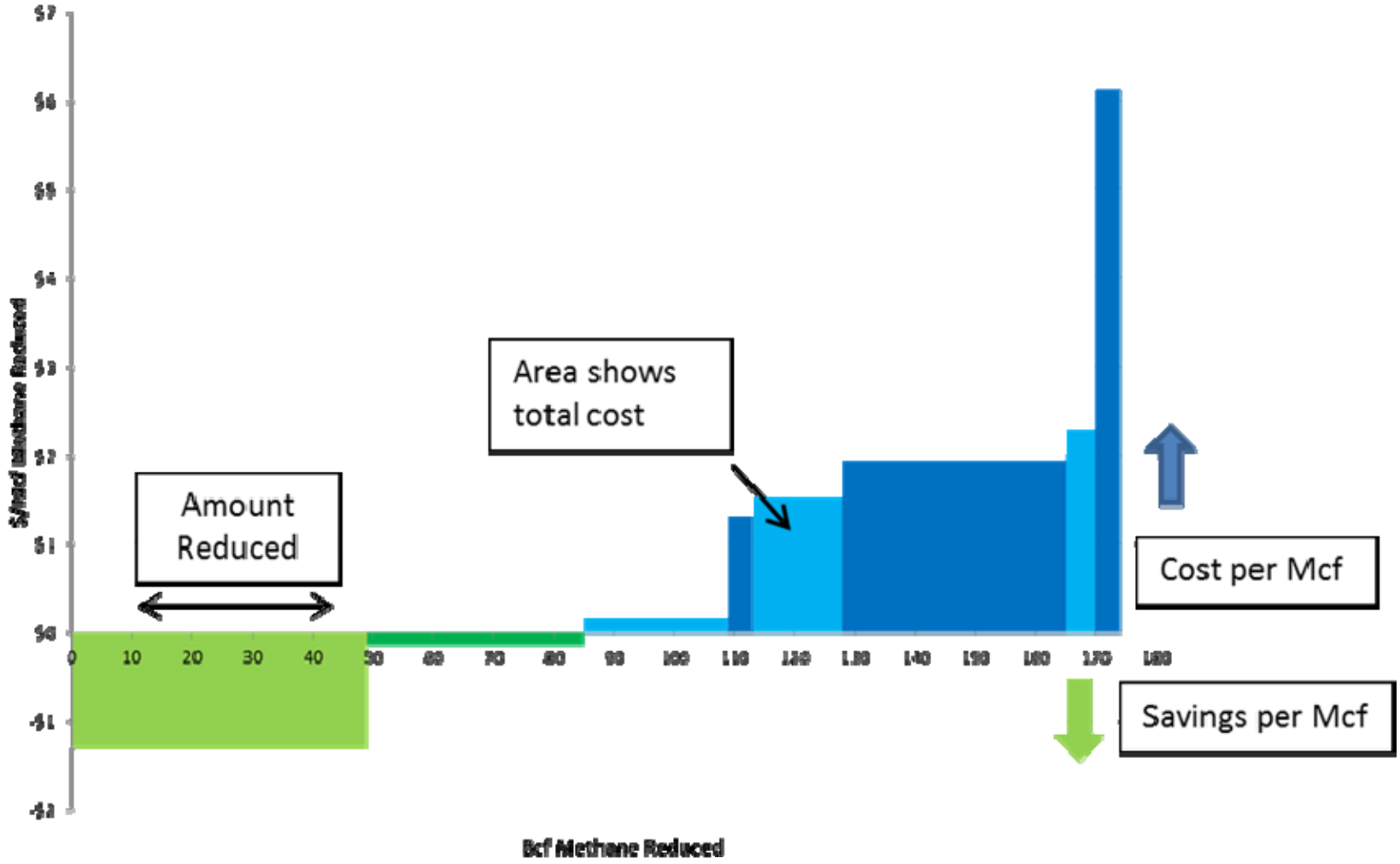
Overview

- What are the Key Questions around Methane Emissions?
- Marginal Abatement Cost (MAC) Curve Concept
- MAC Curve Development Methodology
- Major Opportunities by Country
- Some Caveats to the MAC Curve
- Key Takeaways

What are the Key Questions?

- What is the potential for methane emissions reduction at a country level?
- What control technologies are available?
- How well do they work, i.e. control efficiency?
- What percentage of equipment is already controlled?
- What do these technologies and practices cost?

MAC Curve Concept

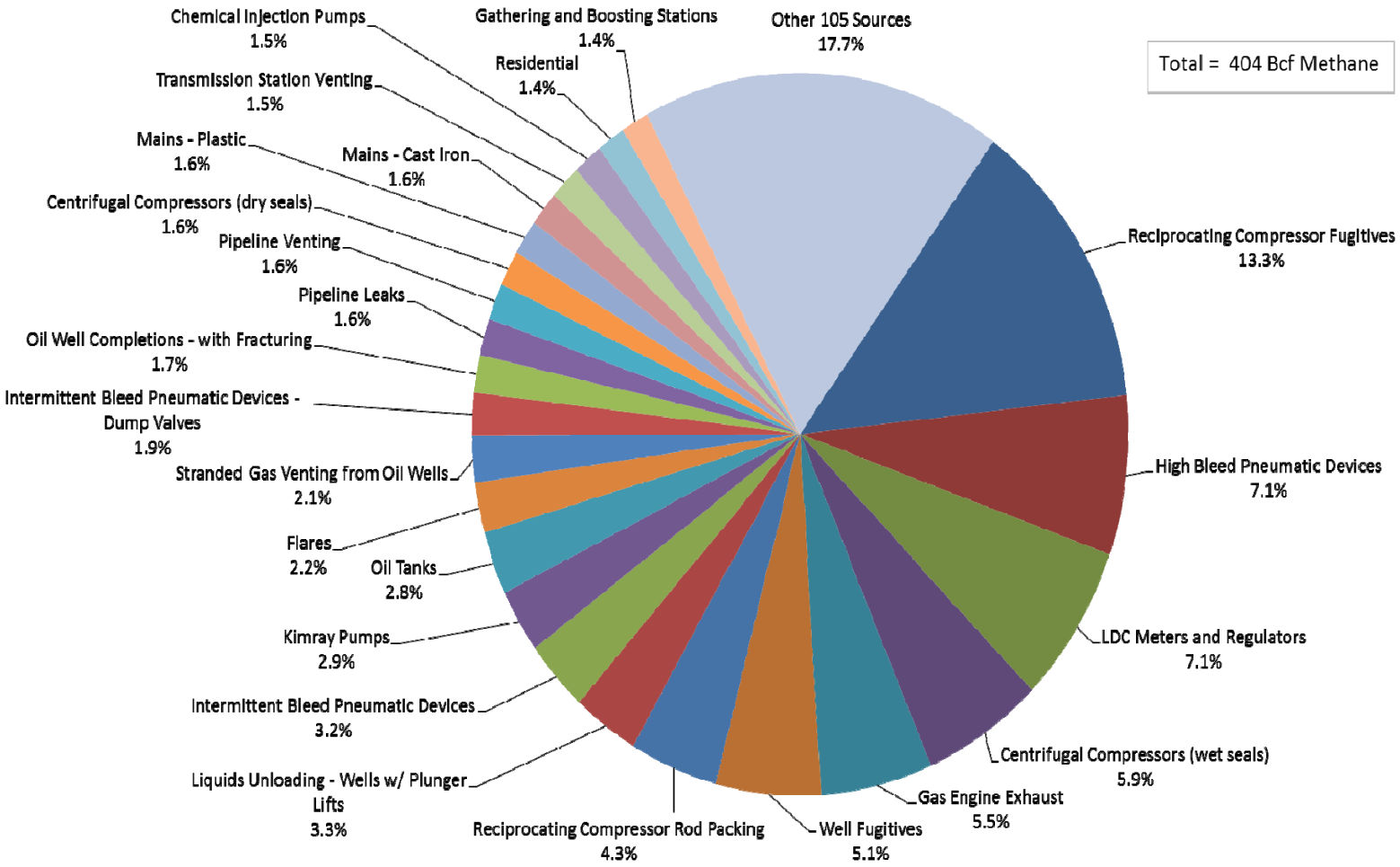


MAC Curve Development Methodology

- **Developed a baseline emissions inventory by emissions source and segment**
  - Source level emissions inventory allows for allocation of specific mitigation measures; over 100 sources analyzed across 9 segments
  - Used activity data specific to each country, such as well count, compressor count, etc.
  - Used latest country specific emissions factors where available
- **Projected base year emissions to 2018 to evaluate emissions mitigation potential**
- **Identified a list of methane emissions mitigation measures and assigned them to relevant emission sources**
  - List includes over 20 mitigation measures
  - Estimated level of control currently in place
  - Determined the applicability of new controls to uncontrolled sources
- **Developed estimates of capital, maintenance, and operational costs for each mitigation measure**
  - Local cost factors included when analyzing different regions
- **Determined annualized cost of implementing mitigation measures per unit reduction of emissions ($ annualized cost per Mcf methane emissions reduced)**

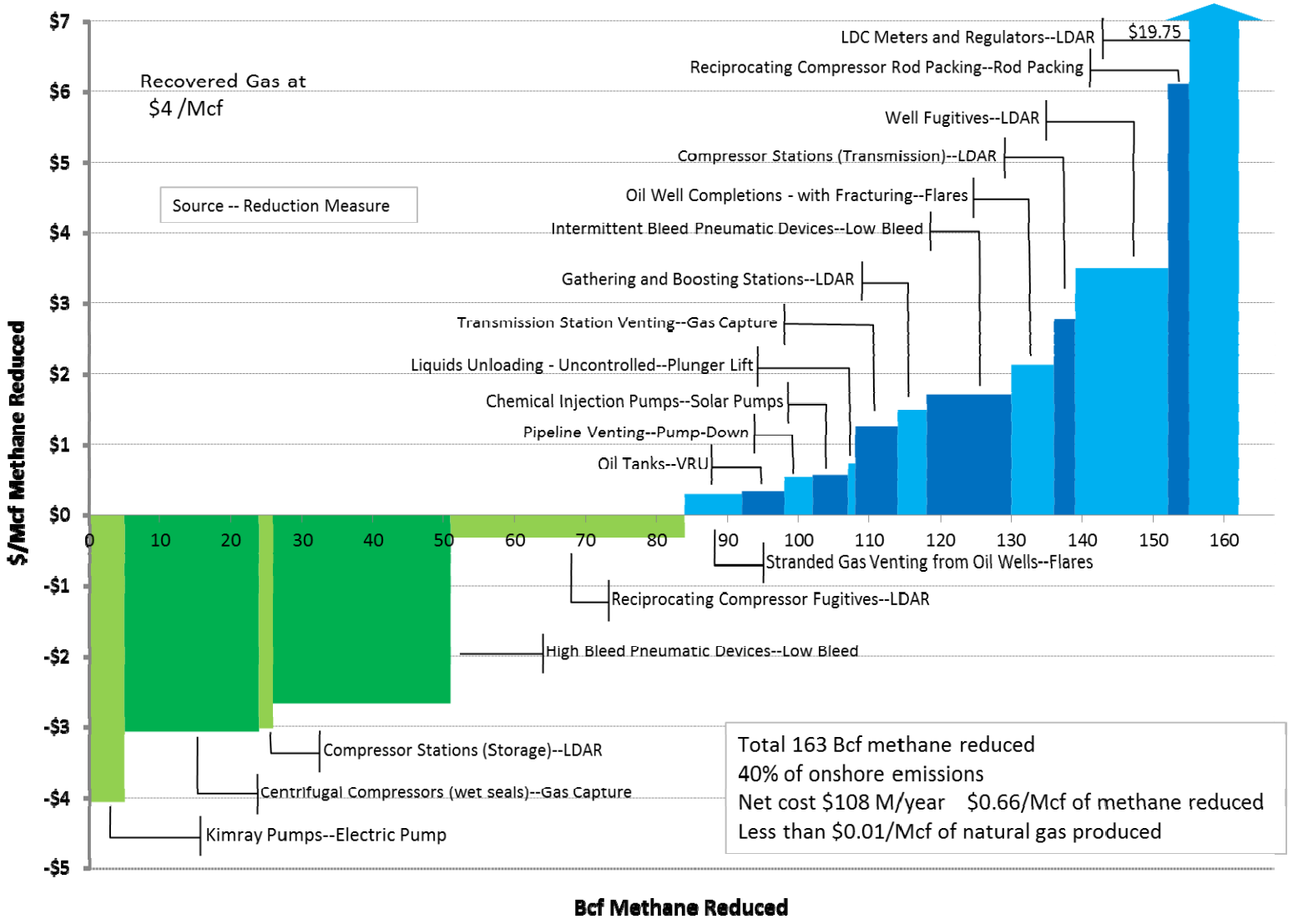
2018 U.S. Onshore Methane Emissions by Source

Top 22 sources ~ 80% of emissions

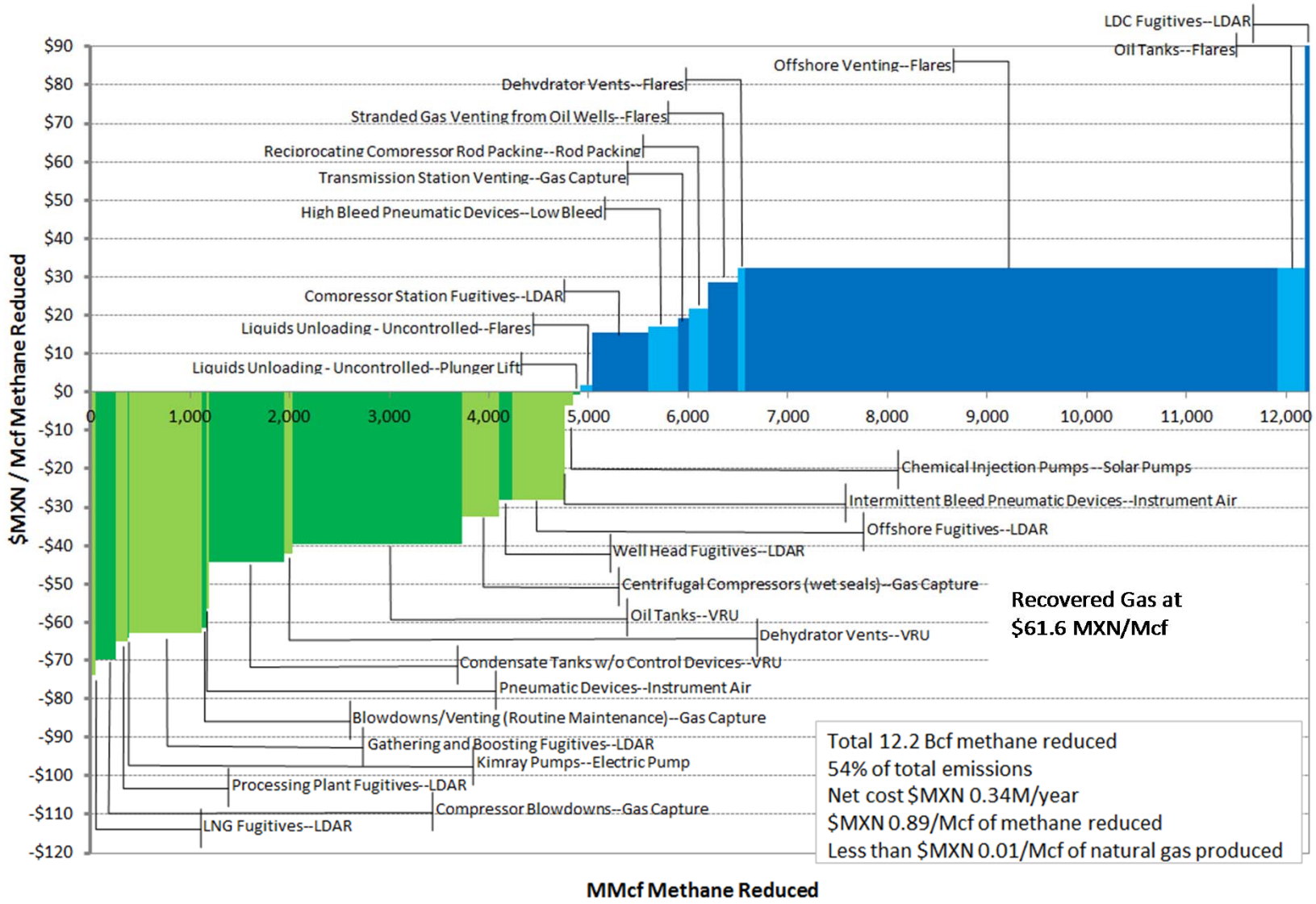


Economic Analysis of Methane Emission Reduction Opportunities in the On-Shore Oil and Natural Gas Industries - 2014

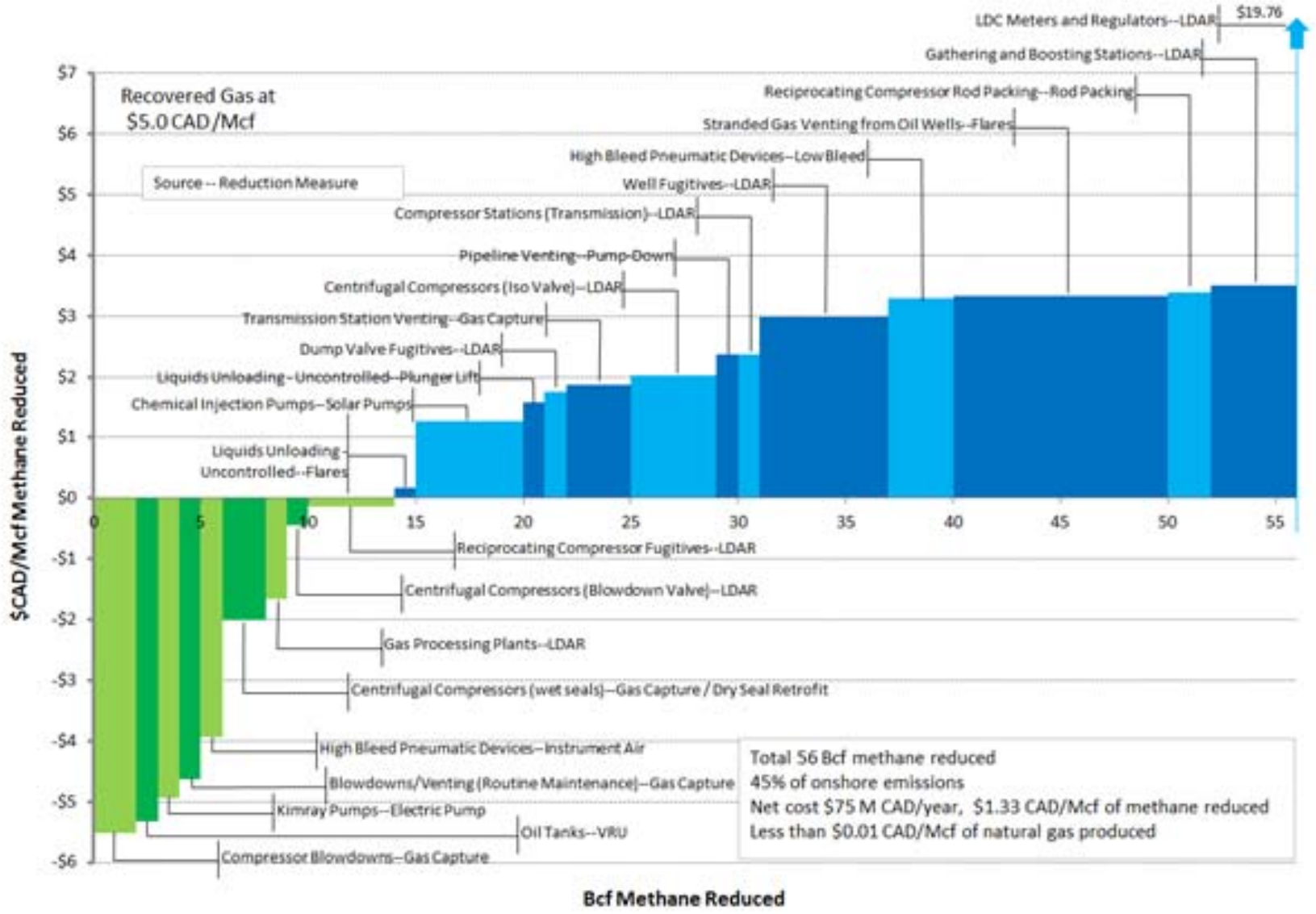
U.S. Sector-wide Abatement Cost Curve



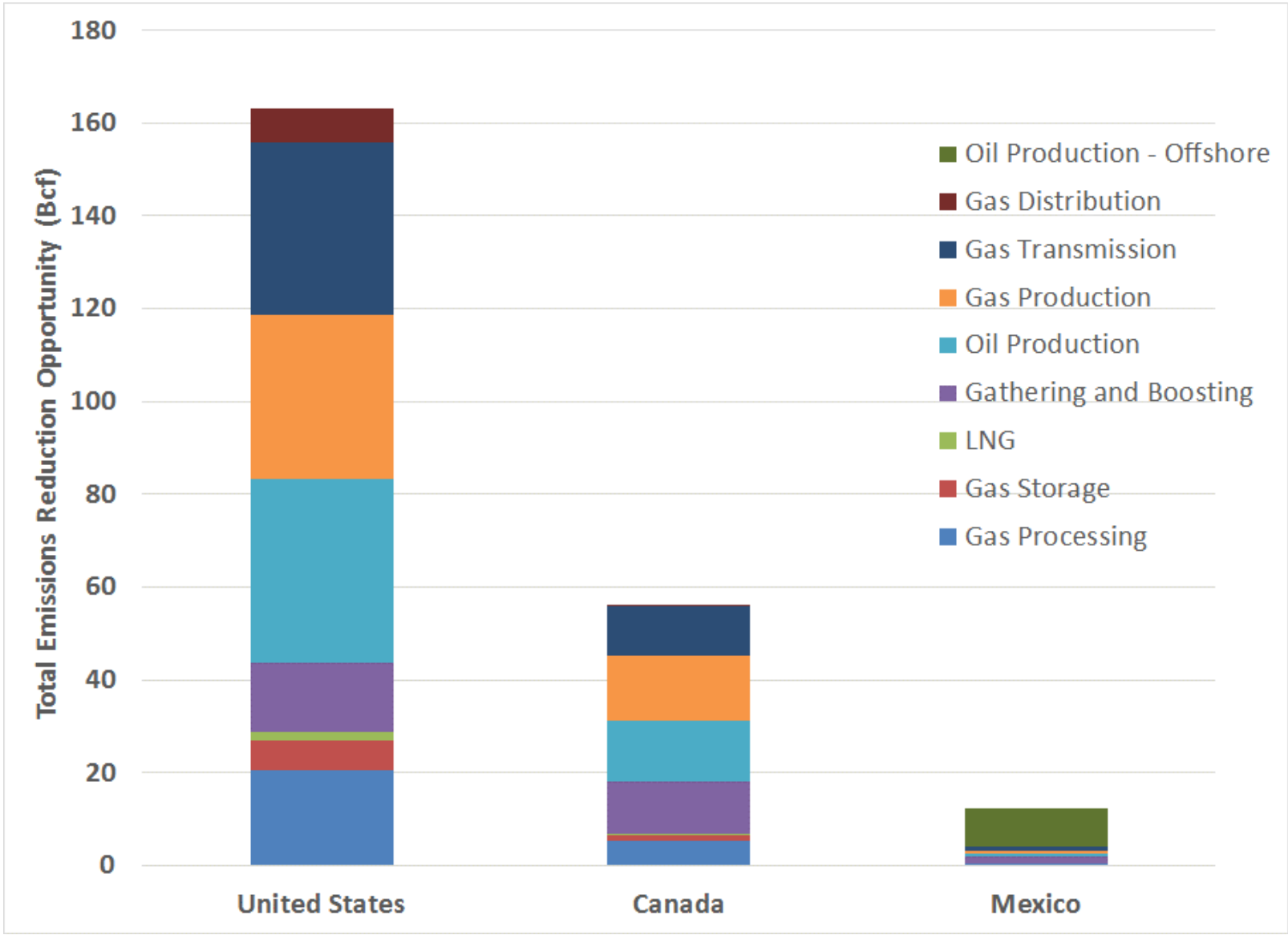
Mexico Sector-wide Abatement Cost Curve



Canada Sector-wide Abatement Cost Curve



Major Reduction Opportunities by Segment



Some Caveats to the MAC Curve

- **The MAC curves provide average economics of mitigation measures**
  - Site specific economics will vary depending on equipment sizing, emissions reduction potential, type of control option, price of gas, etc.
- **New data has been published that can improve the baseline inventory**
- **U.S. MAC was analyzed with base year 2011; companies have implemented control measures since that may not be reflected in the MAC curve**
- **Projections in year 2018 were made using certain assumptions on crude oil and gas prices**

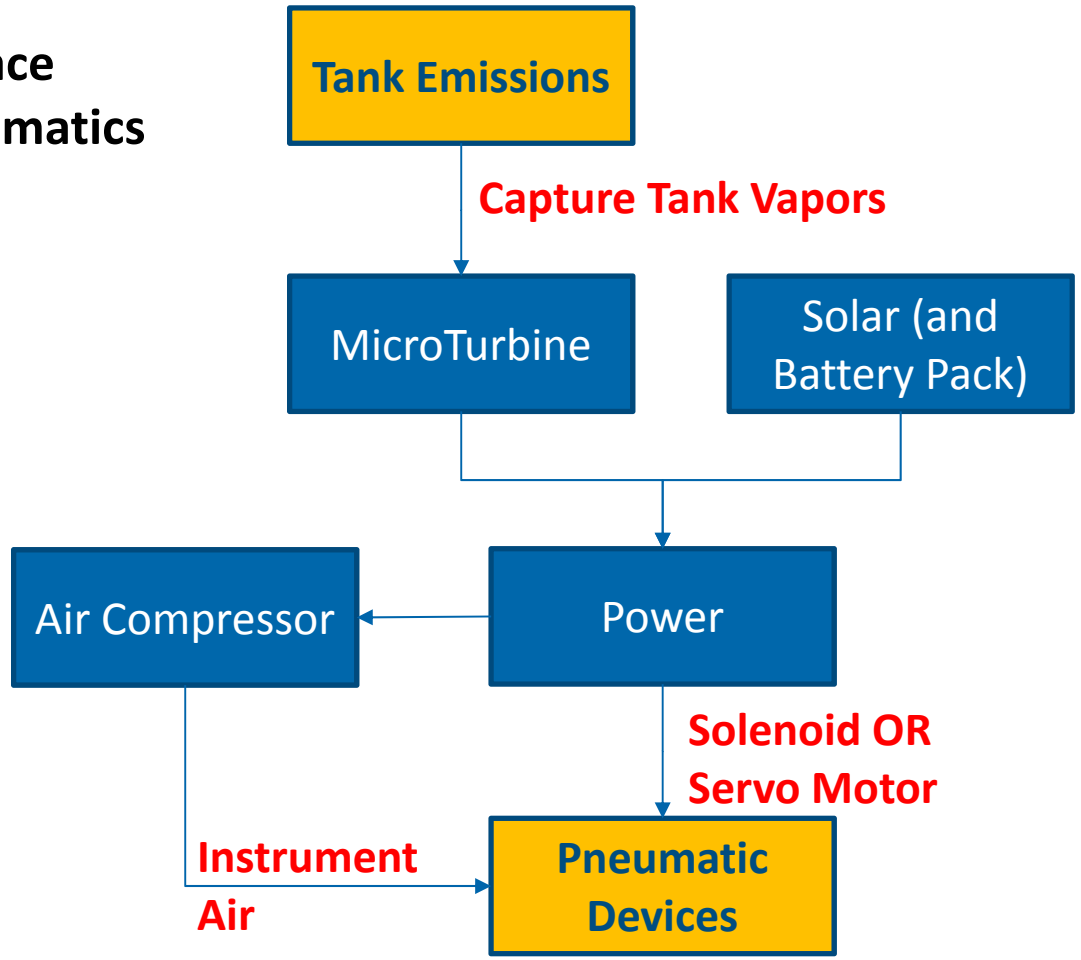
Key Takeaways

- **MAC curves indicate significant potential for methane emissions reductions**
  - 232 Bcf in North America (or 111.7 million metric tonnes CO_2e)
- **MAC curve can be developed in multiple layers and levels - country, state, basin, company, segment, source, etc.**
- **Better characterization of certain emission sources will better inform level of reductions achievable**
  - E.g. Pneumatic device bleed and actuation emissions characterization and rod packing emissions profile over time
- **Not all emission sources have cost-effective mitigation options**
  - Cast-iron replacement
  - Intermittent pneumatic devices
- **Power grid access or renewable energy can mitigate emissions through electrification**

Key Takeaways

- **Ultimately, the best solutions are site-specific**

Example: Replace Wellhead Pneumatics



ICF MAC Curve Report Links

- **United States**
  - https://www.edf.org/sites/default/files/methane_cost_curve_report.pdf
- **Canada**
  - https://www.edf.org/sites/default/files/content/canada_methane_cost_curve_report.pdf
- **Mexico**
  - https://www.edf.org/sites/default/files/mexico_methane_cost_curve_report.pdf

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