Better for global warming?

Leak rate <1% ensures shale gas less of a GHG source than coal/oil (e.g. World Resource Institute, 2012)
Fig. 2—Barnett shale measured fracture heights sorted by depth and compared to aquifers.
Sources of Methane in Water Wells

ANTHROPOGENIC CONTAMINATION (E.G., IMPROPERLY SEALED WELL)

MICROBIAL GAS (PRODUCED IN-SITU IN THE SHALLOW AQUIFER)

NATURAL CONTAMINATION (MIGRATION ALONG A FAULT)

Kohlbecker, GSI 2011
Mixing between in-situ bacterial methane and thermogenic methane from an accumulation at depth results in a wide variation in methane isotope signature.

**THERMOGENIC END-MEMBER**
\[ d^{13}C = -38.3 \text{ \textdegree}_{oo}, C = 931 \text{ mg/L} \]

**BIOGENIC END-MEMBER**
\[ d^{13}C = -88.4 \text{ \textdegree}_{oo}, C = 20 \text{ mg/L} \]

Data from: Early and others (1996)
Methane migration - casing failure

Kohlbecker, GSI 2011
## Failure Frequency

- Low Frequency ....but many wells

<table>
<thead>
<tr>
<th>Drilling Wells</th>
<th>Completed Wells</th>
<th>Wire-Line Logging Wells</th>
<th>Well Workover</th>
<th>Shallow Gas Drilling Wells</th>
<th>Shallow Gas Exploration Wells</th>
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<td>6.0E-05</td>
<td>9.7E-05</td>
<td>6.5E-06</td>
<td>1.8E-04</td>
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</tr>
</tbody>
</table>

OGP, 2010
Studies of Well Failure

Failure Factors:
- Type of Well
- Era of Construction
- Maintenance
- Age of Well
- Design specification
- Construction
- Change of service

Well Type and Estimated Risk of Barrier Failure(s) - How the well use impacts the incident rate.

Low Failure Incident Rate
- Frac New Well
- Offshore - platform well
- Corrosive oil or gas
- HPHT Wells

High Failure Incident Rate
- Fire Flood
- Cyclic Steam
- Corrosive exterior fluids
- Frac- Old Well
- Offshore Subsea
- Horizontal Multi-Frac

Valencia and King, 2013