US EPA Cattle Enteric Fermentation Model (CEFM)

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2000 US Methane Emissions (Tg CO\textsubscript{2}-Eq.)

Total = 614.5 Tg CO\textsubscript{2}-Eq.
Enteric Fermentation Methane Emissions (2000)

Total Enteric = 123.9 Tg CO$_2$-Eq
Basic IPCC Tier 2 Enteric Calculation

- Emissions = EF \times \text{population}
- EF = \frac{(\text{GE} \times Y_m)}{(55.65 \text{ MJ/Kg CH4})}
- \text{population: subcategorized by species}
- \text{GE} = \text{gross energy intake, derived from net energy equations in IPCC Guidelines}
- Y_m = \text{methane conversion rate as \% of GE, affected by feed type and animal}
Steps in Tier 2 Enteric Inventory

- Subcategorize national livestock population
- Develop gross energy estimate (MJ/day) for each animal subcategory
- Gross energy calculation requires performance data on each animal subcategory and feed data
- Agriculture experts needed to develop many of the inputs
Cattle Population Subcategories

Calves < 500 lbs.
Replacement Beef Heifers (7-23 months)
Replacement dairy Heifers (7-23 months)
Other Heifers (7-23 months)
Steers (7-23 months)
On Feed (Heifers + Steers)
Dairy Cows
Beef Cows
Inputs for Animal and Feed Modeling in Tier 2

- Live-weight
- Average weight gain per day
- Mature weight
- Average number of hours worked per day
- Feeding situation
- Average milk production per day
- Fat content of milk
- Percent of females that give birth/year
- Feed digestibility
- Methane conversion rates
EPA Refinement of IPCC Tier 2 Calculation

- Cohorts of cattle subspecies are tracked through the year
- Livestock performance data (e.g., weight gain) are linked to growth stage of animal
- Emissions calculated on a monthly-basis
- Country-specific digestible energy and methane conversion rates
Key Processing Steps in the CEFM

- Build the cattle population matrix
- Diet Characterizations
  - Digestible energy values
  - Methane conversion rates ($Y_m$)
- Calculate emissions based on IPCC energy equations
<table>
<thead>
<tr>
<th>Worksheet</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary</td>
<td>Summary sheets that pull key information for use in the US Greenhouse Gas Inventory</td>
</tr>
<tr>
<td>Summary2</td>
<td></td>
</tr>
<tr>
<td>Summary3-other livestock</td>
<td></td>
</tr>
<tr>
<td>Initial Conditions</td>
<td>Extracts annual input sheet for the year being run</td>
</tr>
<tr>
<td>Beef Rep Heif Wgt</td>
<td></td>
</tr>
<tr>
<td>Dairy Rep Heif Wgt</td>
<td>Tracks weight and weight gain by month for each subcategory</td>
</tr>
<tr>
<td>Other Steer Wgt</td>
<td></td>
</tr>
<tr>
<td>Other Heif Wgt</td>
<td></td>
</tr>
<tr>
<td>Calf Supply</td>
<td>Tracks calf supply accounting for death and slaughter</td>
</tr>
<tr>
<td>Repl Beef Heif D_S</td>
<td>Replacement heifer demand this year</td>
</tr>
<tr>
<td>Repl Dairy Heif D_S</td>
<td></td>
</tr>
<tr>
<td>Other Heif D_S</td>
<td>Calculates the feedlot placement supply</td>
</tr>
<tr>
<td>Other Steer D_S</td>
<td></td>
</tr>
<tr>
<td>Steer Stockers</td>
<td>Available supply of stockers for backgrounding and feedlot placement after subtracting all replacements and those for stock at beginning of next year</td>
</tr>
<tr>
<td>Heifer Stockers</td>
<td></td>
</tr>
<tr>
<td>Combined Stockers</td>
<td></td>
</tr>
<tr>
<td>Steer Feedlot</td>
<td>Tracks animal weight and weight gain while on step up and finishing diets</td>
</tr>
<tr>
<td>Heifer Feedlot</td>
<td></td>
</tr>
<tr>
<td>Cow Pop</td>
<td>Used to back calculate beef and dairy death loss</td>
</tr>
<tr>
<td>1999</td>
<td>Annual input sheets</td>
</tr>
<tr>
<td>DressedSlaughterWeight</td>
<td>Average dressed slaughter weight for all years is calculated for use in 1989-1992 where data is not available</td>
</tr>
<tr>
<td>Cattle Marketed</td>
<td>Average of the number of cattle marketed at &lt;1000 and 1000+ head feedlots for each year available</td>
</tr>
<tr>
<td>Placements</td>
<td>Feedlot placement statistics for each year available</td>
</tr>
<tr>
<td>Slaughter</td>
<td>Calculates scaling factors of number placed in feedlots and number slaughtered</td>
</tr>
<tr>
<td>BeefBirths</td>
<td>Calculates beef births by month based on available data</td>
</tr>
<tr>
<td>Assumptions</td>
<td>Summarizes death loss, cattle weights, and weight class definitions used in model</td>
</tr>
<tr>
<td>Livestock Summary</td>
<td>Summarizes emissions by subcategory and year</td>
</tr>
<tr>
<td>Compare New-Old</td>
<td>Compares output from current model with old methodology from 1990-1998</td>
</tr>
<tr>
<td>Emissions Summary</td>
<td>Summarizes the output from each year by subcategory and region</td>
</tr>
<tr>
<td>Emissions Engine</td>
<td>Drives the model to run specified years and outputs</td>
</tr>
<tr>
<td>Pop Summary</td>
<td>Summarizes the cattle population by sub-category and year</td>
</tr>
<tr>
<td>DEandYm</td>
<td>Shows the DE and Ym for the year being run</td>
</tr>
<tr>
<td>Pregnant</td>
<td>Estimates the percentage of cows pregnant by month</td>
</tr>
<tr>
<td>Beef Lactation</td>
<td>Calculates the weighted average of beef milk production</td>
</tr>
</tbody>
</table>
Example DE & Ym values

- Grazing cattle
  - DE = 62%
  - $Y_m = 6.5\%$

- Dairy cows
  - DE = 69%
  - $Y_m = 5.7\%$

- Feedlot Cattle
  - DE = 85%
  - $Y_m = 3.0\%$

Primarily pasture with some supplements

Pasture, concentrates, and mixed diets

Step-up and finishing diets
US Cattle Populations -2001

Source: USDA, 2002
Methane Emissions from Cattle Enteric Fermentation - 2001

United States (AK & HI Inset)

- 3.4 to 13.8 (9)
- 2.2 to 3.4 (11)
- 1.3 to 2.2 (9)
- 0.5 to 1.3 (8)
- 0 to 0.5 (13)
Cattle Enteric Methane Emissions
1990 - 2001

Methane Emissions (Gg)

Year

Direct Measurement Data for Enteric Emissions

- Measurements for validation and new EF development
- Calorimeter chambers (basis for some of current default EFs)
- SF-6 Tracer gas technique
  - Field tested in US, Canada, Australia, South America
- Head-box chambers
  - ILRI research in Africa
CEFM results

- 6% increase in annual methane emissions as compared to previous method
- Current emission trends reflect decreasing populations and improved feeds/productivity
- Allows user to model changes in the cattle production industry
- Now using model output on waste energy production to estimate manure production
What’s next?

- Evaluate uncertainties in $Y_m$
- Modeling regional and local variations in feed and feed management practices
- How to project improvements in feeds/management practices on methane impact
- Compare/validate CEFM results to direct measurement results