Measuring energy

- **Joule** [J], International System of Units (SI)
- **Calorie** [cal]
  - International Table calorie: 1 cal = 4.1868 J (exact)
  - There are other equivalences
- **Thermie** [th]
  - 1 th = 1000 kcal = 1 Mcal
- **British thermal unit** [Btu]
  - International Table, Btu IT.
    - 1 Btu = 251.99579631 cal ≈ 252 cal
    - 1 Btu = 1055.06 J
    - 1 MBtu = 10^6 Btu (sometimes mmBtu)
- **Kilowatt-hour** (kWh)
  - 1 kWh = 3.6 x 10^6 J (exact)
  - 1 kWh = 3412.14 Btu (IT) = 0.859845 Mcal
  - 1000 kWh = 1 MWh
  - 1000 MWh = 1 GWh
  - 1000 GWh = 1 TWh
Ammount of fuel

- How do we measure quantities of fuel?
  - 1 barrel [bbl] ≈ 159 L (unit not universally standardized)
  - 1 tonne [t] = 1000 kg
  - 1 billion cubic meters of natural gas [bcm]
  - 1 Normal cubic meter of Natural Gas [Nm³]
  - 1 m³ LNG = 583 Nm³
Energy in terms of the amounts of fuel?

• It is necessary to define a certain energy content.

• About the heating value:
  – Higher heating value (\textbf{HHV}) (kcal/kg), it assumes all the water component is in liquid state at the end of combustion (in product of combustion)
  – Lower heating value (\textbf{LHV}) (kcal/kg), (also called net calorific value, NCV) It is the quantity of heat produced by combustion when the water produced by combustion remains gaseous.

• The standard “coal” and “oil” satisfy:
  →
  – 1 tonne of coal equivalent (tce) = 7000 Mcal \quad \text{LHV}= \, 7.000 \, \text{kcal/kg}
  – 1 tonne of oil equivalent (toe) = 10000 Mcal

• The equivalences are:
  – 1 barrel of oil equivalent [boe] = 5.80 MBtu
  – 1 Ton of oil equivalent [toe] = 39.6832 Mbtu = 11.63 MWh = 41.868 GJ
  – 1 Ton of coal equivalent [tce] = 27.778 MMBtu = 8.141 MWh = 29.308 GJ
  – 1 tce = 7000 th
  – 1 tce = 0.70 toe
  – 1 toe = 1.4286 tce
## Conversion table

<table>
<thead>
<tr>
<th>From:</th>
<th>To:</th>
<th>TJ</th>
<th>Gcal</th>
<th>Mtoe</th>
<th>MBtu</th>
<th>GWh</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>multiply by:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TJ</td>
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<td></td>
<td>238.8</td>
<td>2.388 × 10⁻⁵</td>
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<tr>
<td>Gcal</td>
<td>4.1868 × 10⁻³</td>
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<td></td>
<td>10⁻⁷</td>
<td>3.968</td>
<td>1.163 × 10⁻³</td>
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<tr>
<td>Mtoe</td>
<td>4.1868 × 10⁴</td>
<td>10⁷</td>
<td></td>
<td>1</td>
<td>3.968 × 10⁷</td>
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<tr>
<td>MBtu</td>
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<td>0.252</td>
<td>2.52 × 10⁻⁸</td>
<td>1</td>
<td>2.931 × 10⁻⁴</td>
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<tr>
<td>GWh</td>
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<td>860</td>
<td>8.6 × 10⁻⁵</td>
<td>3412</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: International Energy Agency (IEA), US DOE