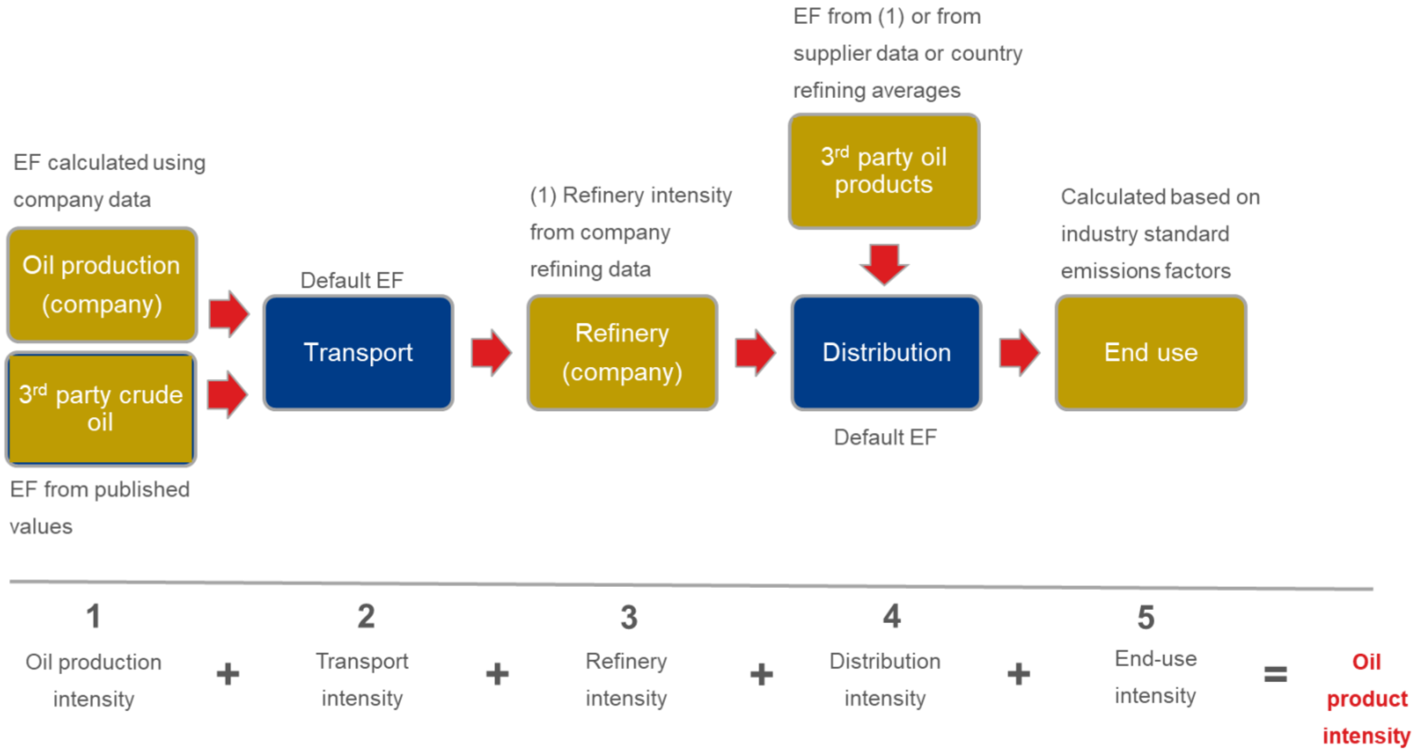
# *Annex D – Fuel specific calculations for the WTW indicator*

## *Oil*

The next figure[1] shows the steps of the Oil supply-chain that shall (light brown) and should (blue) considered for the calculation of the Well-to-Wheel GHG intensity of oil.




[1] This figure considers a company where the marketing segment sets its net volume. For other type of company configurations, some of the arrows might be inverted, e.g. a company where refining would set the net volume, would likely export oil products to 3rd parties instead of importing them for final sales to end user; or a company operating mainly upstream would have net crude oil exports (and not imports).

The calculation of the final carbon intensity of the oil delivered will be an average of own oil throughput through own assets, using company-specific emission factors and bought products and/or services using non-company specific emission factors. Companies will sell a variety of oil derived energy products, with slightly different characteristics across different markets. Companies should use their own data for the characterization of those products but may use default factors referenced in tables D.Oil.1 to D.Oil.5.

| **Table D.Oil.1 – Emission calculations for the Oil supply chain** | | | | |
|---|---|---|---|---|
| **Step** | **Activity data** | **Emission factors** (GHG intensity of) | **EF Source** | **Emissions calculation** |
| *Upstream activities* | | | | |
| 1 | Oil production *[pr]*[2] | Oil produced (kg$CO_2$e/boe) *[$EF_{pr}$]* | Own emissions data[3] | *[pr] * [$EF_{pr}$]* |
| 2 | Oil transported *[pr]* | Oil transportation in pipeline (g$CO_2$e/MJ.km) [$EF_{pp}$] | Own emissions data<br>Use GREET model to estimate an EF per mode of transportation[4] | *[pr]* [$EF_{pp}$]* |
| 1-2 | 3rd party crude inputs *[tpi]* | Full upstream EF of oil produced (kg$CO_2$e/boe) [$EF_{Up}$] | Supplier data[5]<br>Masnadi *et al.*, 2018 country data (Table D.3) | *[tpi] * [$EF_{Up}$]* |
| *Midstream activities* | | | | |
| 3 | Refinery output [Ro] | Refined oil products (kg$CO_2$e/MJ) [$EF_{Ro}$] | Own data | *[Ro] * [$EF_{Ro}$]* |
| 3 | 3rd party oil product inputs [*tpopi*] | Refined oil products (kg$CO_2$e/MJ) [$EF_{Ro}$] | Own data or supplier data<br>Jing *et al.*, 2020 oil supply country data (Table D.4. Refining) | *[tpopi]* [$EF_{Ro}$]* |
| 1-3 | 3rd party oil product inputs [*tpopi*] | Upstream + Refined oil products (kg$CO_2$e/MJ) [$EF_{UpRo}$] | Supplier data[4]<br>Jing *et al.*, 2020 refining country data (Table D.5.Refining+Upstream) | *[tpopi]* [$EF_{UpRo}$]* |
| 4 | Distribution [*Sales*] | Oil product distribution (g$CO_2$e/MJ) [$EF_{distr}$] | Own data or supplier data<br>1 g$CO_2$e/MJ of delivered fuel[6] | *[Sales] *[$EF_{distr}$]* |
| *Downstream activities* | | | | |
| 5 | End use [*Sales*] | Combustion of fuels [$EF_{fuel}$] | Own data<br>Use Low Heating Value $CO_2$ emission factors provided in (IPCC,2006) Tables 2.2 to 2.5, pp. 2.16 to 2.23). If not available, use Tables 4-3 and 4-4 of (API, 2009), pp. 4-17 to 4-20 | *[Sales]* [$EF_{fuel}$]* |

[22] *[pr]* production, is calculated excluding non-energy uses and expressed in energy content. All other volumes *[Ro]*, *[tpi]*, *[tpopi]* and *[Sales]* are also expressed in energy.

[3] Where associated gas is also produced, allocation of emissions between Oil and Gas shall be done using the co-product displacement method.

[4] GREET emission factors might be expressed in MJ.km in which case companies shall document the distances their products travel between production and refinery for each geography.

[5] Companies are welcome to engage with their suppliers and request if they have supplier specific information about the crude oil they provide for each region and distances their products travel between production and refinery. If supplier data is used its shall be documented in the methodology, with a brief explanation of how it has been derived.

[6] Joint Research Council, European Commission (2014), WELL-TO-TANK Report Version 4.a, JEC WELL-TO-WHEELS ANALYSIS, section 3.1.4, pp. 29.

Companies shall use net volumes for calculations and adjust the energy delivered to secondary energy as per Table D.2.

| **Table D.Oil.2 – Energy calculations for the Oil supply chain** | |
|---|---|
| **Net volume** | **Conversion calculations** |
| Production | Adjust crude oil production volumes (expressed as LHV energy content) to consider Refinery efficiency ($\eta_R$) to output of refined oil products. Use reference value of 9.9%[7], or derive factors dependent on crude origin from Supplementary Table 5 in Jing *et al.* |
| Refinery | Refined oil energy products at refinery gates. No conversion needed. Use own values or LHV provided in Table 3-8 of (API, 2009) pp. 3-20 and 3-21. |
| Marketing | Refined oil energy products at refinery gates. No conversion needed. Use own values for products or LHV provided in Table 3-8 of (API, 2009) pp. 3-20 and 3-21. |

**Table D.Oil.3 - Full upstream EF of oil produced** (Masnadi *et al.*, 2018, calculated using the co-product displacement method)[8]

| **Country** | **g CO2eq/MJ** | **Country** | **g CO2eq/MJ** | **Country** | **g CO2eq/MJ** | **Country** | **g CO2eq/MJ** | **Country** | **g CO2eq/MJ** |
|---|---|---|---|---|---|---|---|---|---|
| Syria | 29.8 | Iraq | 14.1 | Guatemala | 9.8 | Papua New Guinea | 8.5 | China | 7.0 |
| Democratic Republic of Congo | 29.2 | Gabon | 13.2 | Lithuania | 9.7 | Turkey | 8.4 | Kuwait | 6.9 |
| Uzbekistan | 27.4 | Malaysia | 12.9 | Russian Federation | 9.7 | Colombia | 8.3 | Qatar | 6.5 |
| Yemen | 26.9 | Nigeria | 12.6 | Kazakhstan | 9.7 | Afghanistan | 8.3 | Equatorial Guinea | 6.4 |
| Albania | 23.7 | Pakistan | 12.2 | Kyrgyzstan | 9.4 | Suriname | 8.2 | Jordan | 6.3 |
| Algeria | 20.3 | Ukraine | 11.8 | Tajikistan | 9.4 | Poland | 8.2 | Azerbaijan | 6.3 |
| Venezuela | 20.3 | Oman | 11.7 | Morocco | 9.3 | New Zealand | 8.2 | Cote d'Ivoire | 6.1 |
| Myanmar | 20.2 | Philippines | 11.6 | Ecuador | 9.3 | United Kingdom | 7.9 | Italy | 6.1 |
| Cameroon | 18.4 | Niger | 11.3 | Barbados | 9.3 | Hungary | 7.9 | Greece | 5.9 |
| Canada | 17.6 | United States | 11.3 | Argentina | 9.1 | Croatia | 7.8 | Brunei | 5.7 |
| Iran | 17.1 | Chile | 11.2 | Australia | 9.1 | Germany | 7.7 | Norway | 5.6 |
| Turkmenistan | 15.9 | Libya | 11.0 | Cuba | 9.0 | Japan | 7.7 | Ghana | 5.2 |

[7] Calculated from average value reported in Jing *et al.* of 606 MJ/bbl
[8] As reported in "Supplementary Material" to Masnadi *et al.*, 2018

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tunisia | 15.4 | Peru | 10.9 | Bolivia | 9.0 | Serbia | 7.7 | Thailand | 5.1 |
| Indonesia | 15.3 | Republic of Congo | 10.6 | Latvia | 8.9 | Austria | 7.6 | Bahrain | 5.0 |
| Georgia | 15.2 | Egypt | 10.6 | Vietnam | 8.8 | France | 7.5 | Saudi Arabia | 4.6 |
| Sudan | 14.9 | Brazil | 10.3 | Belize | 8.8 | Angola | 7.5 | Spain | 4.1 |
| Mauritania | 14.8 | Chad | 10.2 | Bulgaria | 8.6 | Romania | 7.4 | Netherlands | 3.9 |
| Trinidad and Tobago | 14.3 | Mexico | 9.9 | India | 8.6 | United Arab Emirates | 7.1 | Denmark | 3.3 |

| **Table D.Oil.4 – Refining carbon intensity for oil supply countries** (Jing *et al.*, 2020,)[9] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Country** | **g CO2e/MJ** | **Country** | **g CO2e/MJ** | **Country** | **g CO2e/MJ** | **Country** | **g CO2e/MJ** | **Country** | **g CO2e/MJ** |
| Albania | 9.0 | China | 9.0 | India | 8.6 | Pakistan | 5.6 | Tunisia | 6.4 |
| Algeria | 5.3 | Colombia | 7.8 | Indonesia | 7.9 | Papua New Guinea | 6.7 | Turkey | 8.0 |
| Angola | 8.0 | Congo | 9.6 | Iran | 6.9 | Peru | 6.4 | Turkmenistan | 5.3 |
| Argentina | 8.3 | Croatia | 6.3 | Iraq | 7.5 | Philippines | 3.2 | Ukraine | 6.8 |
| Australia | 5.9 | DR of Congo | 6.2 | Italy | 6.8 | Poland | 7.2 | UAE | 6.5 |
| Austria | 8.8 | Denmark | 4.1 | Kazakhstan | 6.3 | Qatar | 6.8 | UK | 7.1 |
| Azerbaijan | 6.7 | Ecuador | 7.3 | Kuwait | 7.1 | Romania | 7.5 | USA | 7.4 |
| Bahrain | 8.0 | Egypt | 5.9 | Libya | 5.9 | Russia | 7 | Uzbekistan | 6.0 |
| Brazil | 8.4 | Eq.Guinea | 7.1 | Malaysia | 6.6 | Saudi Arabia | 7.2 | Venezuela | 7.5 |
| Brunei | 7.5 | France | 6.4 | Mexico | 7.3 | Sudan | 8.5 | Vietnam | 7.1 |
| Cameroon | 10.1 | Gabon | 6.3 | New Zealand | 6.1 | Syria | 3.3 | Yemen | 6.2 |
| Canada | 8.1 | Germany | 6.0 | Nigeria | 6.9 | Thailand | 7.9 | | |
| Chad | 9.0 | Ghana | 6.1 | Norway | 6.2 | Trinidad and Tobago | 6 | | |
| Chile | 7.9 | Hungary | 6.6 | Oman | 7.8 | | | | |

[9] As reported in "Supplementary Information" (Jing *et al.*, 2020), Supplementary Table 2. These values represent the global average carbon intensity of crude oils originating from these countries.

**Table D.Oil.5 – Upstream and Refining carbon intensity of refinery products in given country** (Jing *et al.*, 2020,)[10]

| Country | g CO2e/MJ | Country | g CO2e/MJ | Country | g CO2e/MJ | Country | g CO2e/MJ | Country | g CO2e/MJ |
|---|---|---|---|---|---|---|---|---|---|
| Algeria | 19.8 | Croatia | 36.8 | Israel | 37.0 | Peru | 34.7 | Syria | 18.6 |
| Angola | 14.9 | Cuba | 15.6 | Italy | 36.0 | Philippines | 45.2 | Taiwan | 38.7 |
| Argentina | 0 | Curacao | 31.7 | Japan | 37.1 | Poland | 51.3 | Thailand | 35.9 |
| Australia | 36.5 | Czech | 22.2 | Jordan | 19.5 | Portugal | 37.9 | Trinidad and Tobago | 24.6 |
| Austria | 36.3 | Denmark | 18.4 | Kazakhstan | 29.9 | Qatar | 31.8 | | |
| Azerbaijan | 29.5 | Ecuador | 20.3 | Kuwait | 37.8 | Romania | 43.4 | Turkey | 43.6 |
| Bahrain | 39.9 | Egypt | 22.0 | Libya | 15.8 | Russian | 33.9 | Turkmenistan | 29.2 |
| Belarus | 48.2 | Finland | 51.2 | Lithuania | 26.0 | Saudi Arabia | 41.5 | Ukraine | 37.5 |
| Belgium | 27.6 | France | 32.4 | Malaysia | 36.3 | Serbia | 33.3 | United Emirates | 33.8 |
| Bosnia Herzegovina | 16.6 | Germany | 41.4 | Mexico | 34.0 | Singapore | 35.0 | United Kingdom | 34.3 |
| Brazil | 43.7 | Greece | 31.3 | Morocco | 42.0 | Slovakia | 62.1 | USA | 44.4 |
| Bulgaria | 34.3 | Hungary | 37.6 | Netherlands | 44.7 | South Africa | 39.0 | Uruguay | 36.4 |
| Canada | 38.5 | India | 50.4 | New Zealand | 39.5 | South Korea | 40.3 | Uzbekistan | 33.0 |
| Chile | 46.7 | Indonesia | 37.1 | Nigeria | 29.2 | Spain | 41.7 | Venezuela | 24.8 |
| China | 50.0 | Iran | 36.0 | Norway | 36.4 | Sudan | 42.3 | Vietnam | 37.5 |
| Colombia | 27.7 | Iraq | 13.9 | Oman | 18.6 | Sweden | 25.4 | Yemen | 25.1 |
| Cote d'Ivoire | 44.8 | Ireland | 17.2 | Pakistan | 37.1 | Switzerland | 16.0 | | |

The final WTW carbon intensity of the oil products portfolio for a company where the net volume is set downstream will be[11]:

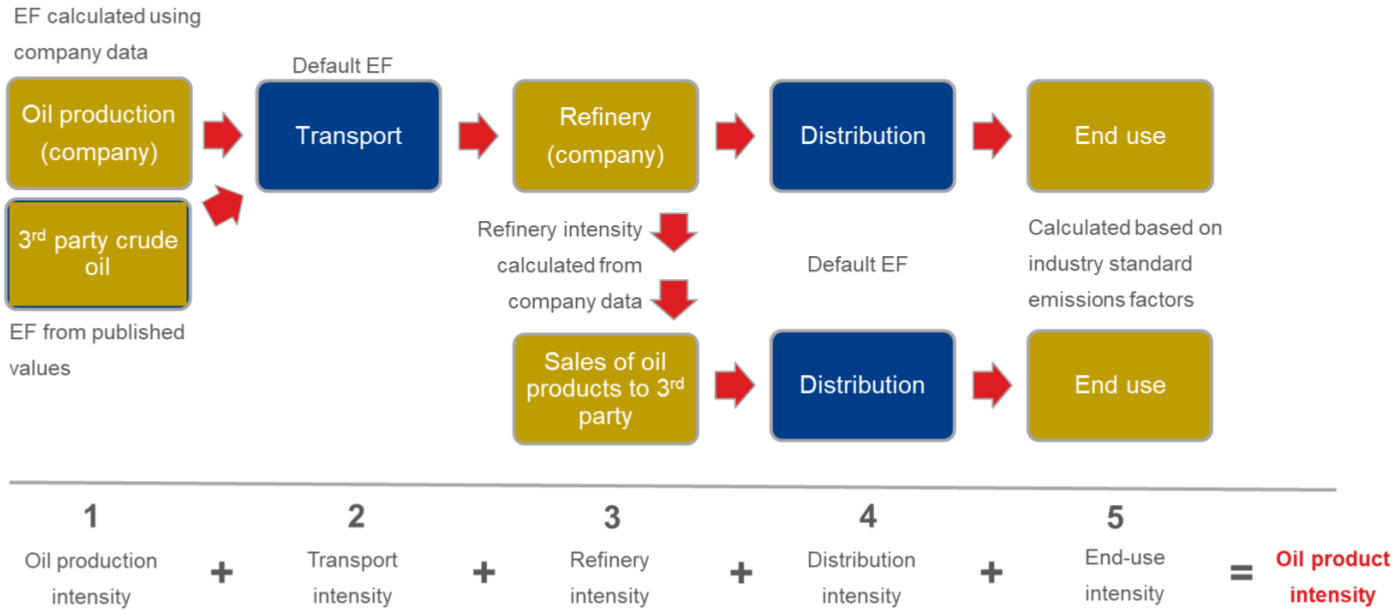
$$CI_{Oil} = \frac{\left[pr * \left(EF_{pr} + EF_{pp}\right) + tpi * EF_{Up}\right] + \left[Ro * EF_{Ro} + tpopi * EF_{UpRo}\right] + Sales * \left(EF_{Distr} + EF_{Fuel}\right)}{Sales}$$

10 As reported in "Supplementary Information" (Jing *et al.*, 2020), Supplementary Table 3. These values represent the full upstream carbon intensity of oil products refined in the country.

11 For the Emission Factors the assumption is that there will be more than one and a weighted average might need to be calculated, for example there will be more than one type of fuel and companies should calculate an average weighted fuel emission factor across their product portfolio.

Companies might need to adjust the equations and units to reflect how their activity data and emission factors are gathered. Calculations might need to be done on a country basis or regional basis and then aggregated to global level. Likewise, companies will need to carefully consider how to apply emission factors depending on which segments defines its net volume – alternative flows are given below for companies where Upstream and Midstream sets their net volume. Companies shall detail any deviations or specifications made in the application of these instructions.

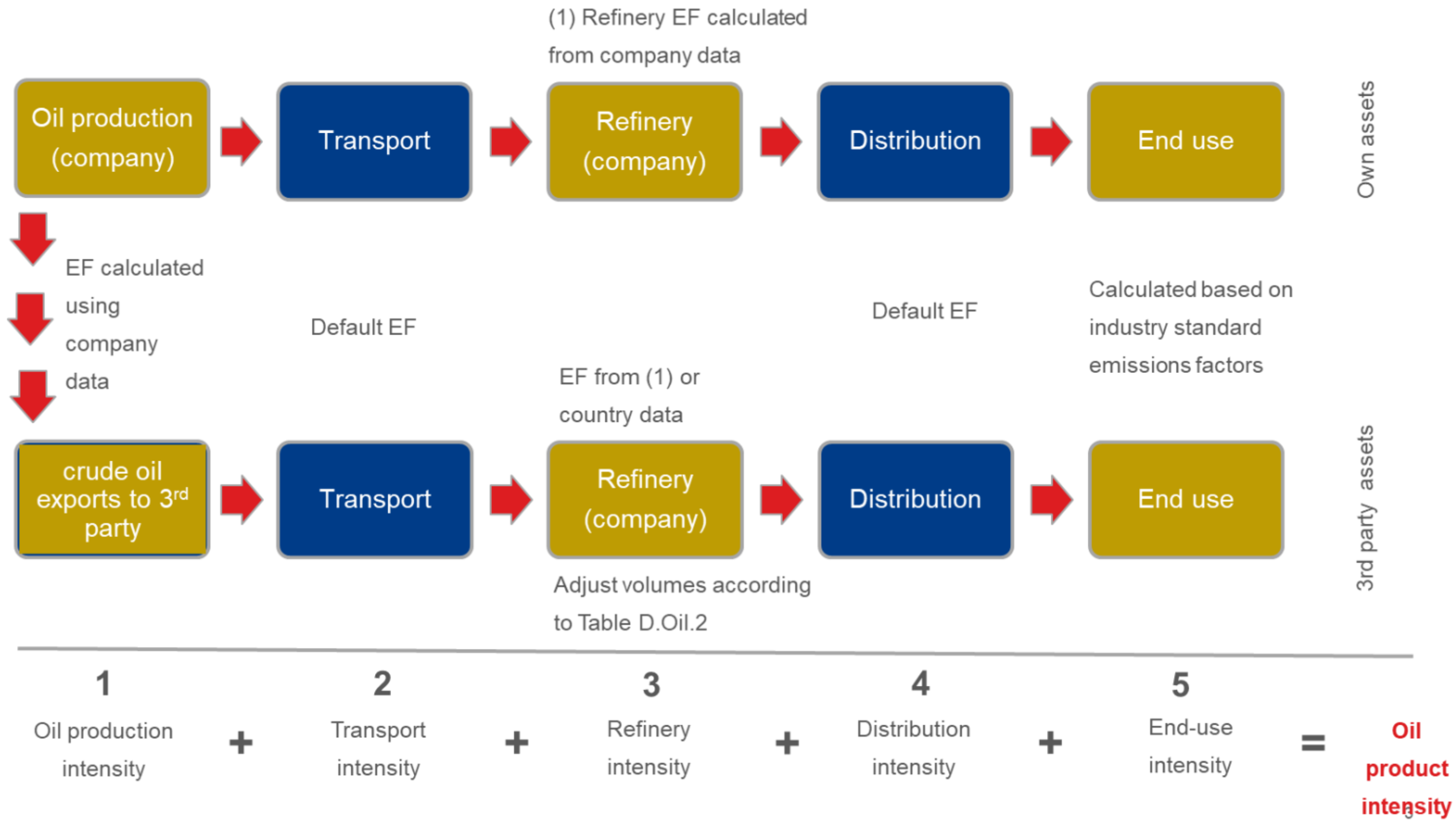
*Net volume Midstream*




The final WTW carbon intensity of the oil products portfolio for a company where the net volume is set midstream will be:

$$CI_{Oil} = \frac{[pr * (EF_{pr} + EF_{pp}) + tpi * EF_{Up}] + [Ro * (EF_{Ro} + EF_{Distr} + EF_{Fuel})]}{Ro}$$

*Net volume Upstream*

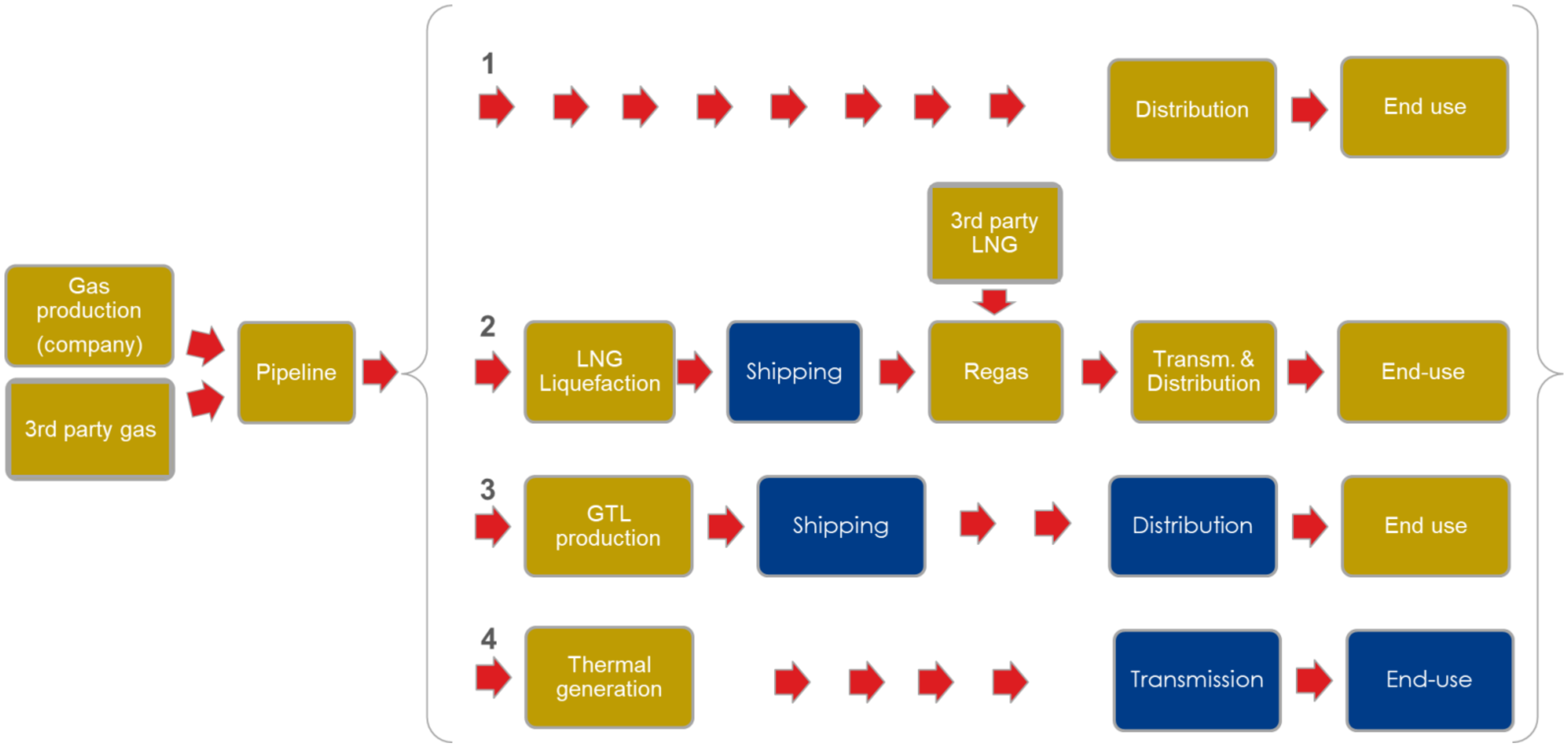



The final WTW carbon intensity of the oil products portfolio for a company where the net volume is set upstream will be:

$$CI_{Oil} = \frac{[pr * (EF_{pr} + EF_{pp} + EF_{Ro} + EF_{Distr} + EF_{Fuel})]}{(1 - \eta R) * pr}$$

### *Gas*

The next figure shows the steps of the full gas supply-chain that shall (light brown) and should (blue) be considered for the calculation of the Well-to-Wheel GHG intensity of gas.

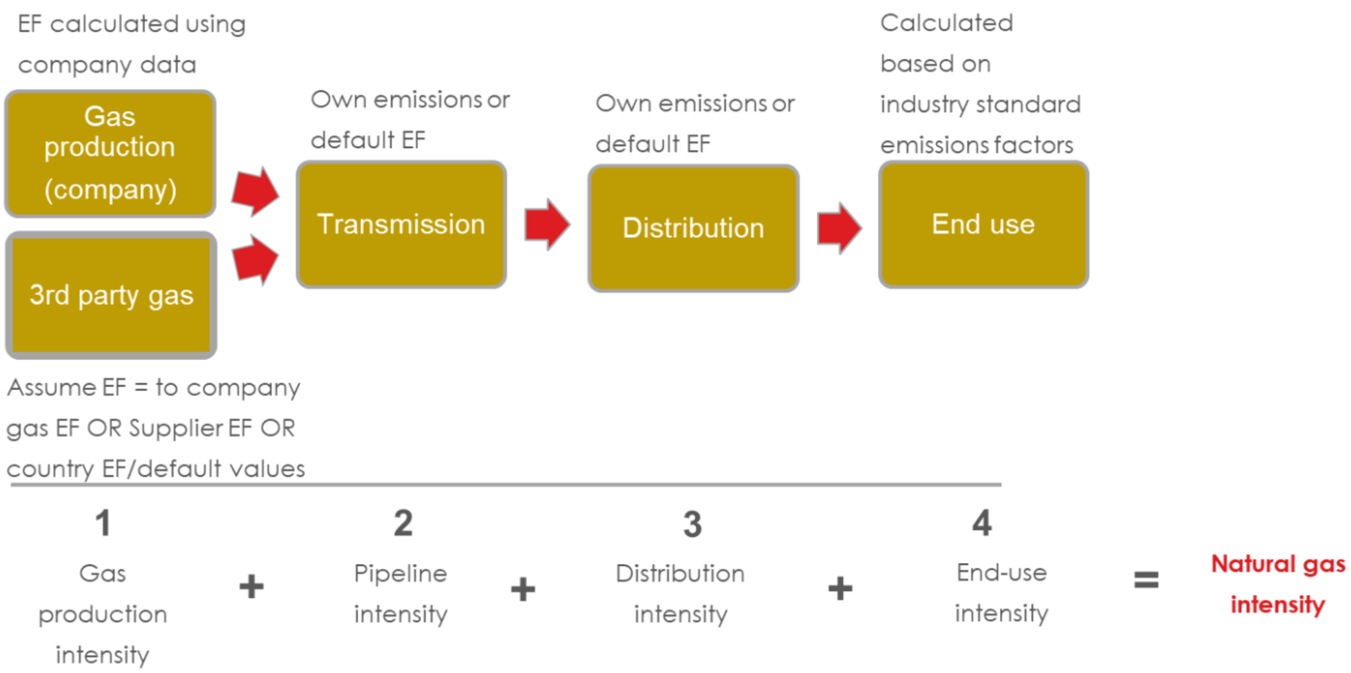



Gas produced by a company can have 4 main routes:

1. Natural Gas sent to Gas sales to final customer (end user);
2. Natural gas to LNG for further transportation to a final destination, regasification and then sales to end-user;
3. Gas to Liquid, where gas is transformed into liquid fuel, further transported and distributed to end-user;
4. And Gas to Electricity, where gas is transformed into electricity, injected into the grid and distributed to end-user.

This section focuses on the first route. Route 2 and 3 are dealt in their own sections and route 4 "Gas to electricity" is dealt within the "Electricity" section. In principle all gas produced will go to one of these routes, whether this occurs within own assets or 3rd party (client) assets. Companies however, might sell to others and buy from others and so the principles of net volume accounting apply. Companies should calculate net volumes of gas on a regional/market level but may calculate it at country level.

Route 1, "Natural Gas to Gas sales" is the simplest one and is shown in next figure[12]. As before, this route is illustrated for a company where downstream marketing activities set the net volume.




The calculation of the final carbon intensity of the gas delivered will be an average of own gas throughput through own assets, using company-specific emission factors and bought products and/or services using non-company specific emission factors. Companies should use their own data for the characterization of those products but may use default factors referenced in tables D.Gas.1 to D.Gas.3.

[12] This figure considers a company where the downstream marketing segment sets its net volume.

| Table D.Gas.1 – Emission calculations for the Gas supply chain | | | | |
|---|---|---|---|---|
| **Step** | **Activity data** | **Emission factors** (GHG intensity of) | **EF Source** | **Emissions calculation** |
| *Upstream activities* | | | | |
| 1 | Gas production *[pr]*[13] | Gas produced (g$CO_2$e/MJ) *[$EF_{pr}$]* | Own emissions data[14] | *[pr] * [$EF_{pr}$]* |
| *Midstream activities* | | | | |
| 2 | Gas transmission *[pr]* | Gas transportation in pipeline (g$CO_2$e/MJ) [$EF_{pp}$] | Own emissions data or country data<br>Default value pipeline losses of 0.35%. See table D.Gas.2. | *[pr]* [$EF_{pp}$]* |
| *Downstream activities* | | | | |
| 3 | Gas distribution *[pr]* | Gas distribution network (g$CO_2$e/GJ) [$EF_{distr}$] | Own emissions/client data.<br>Default value of default of 0.16% OR country values. See table D.Gas.2. | *[pr]* [$EF_{distr}$]* |
| 1-3 | 3rd party gas inputs *[tpg]* | Full upstream EF of gas produced (g$CO_2$e/MJ) [$EF_{Up}$] | Supplier data[15]<br>Default value of 16.09 g$CO_2$e/MJ. See table D.Gas.3. | *[tpg] * [$EF_{Up}$]* |
| 4 | End use [*Sales*] | Combustion of fuels [$EF_{fuel}$] | Own data<br>Use (IPCC,2006) value of 56.1 t$CO_2$/TJ | *[Sales]* [$EF_{fuel}$]* |

| Table D.Gas.2 – Gas losses in Transmission and distribution | |
|---|---|
| **Transmission** | Use default value of 0.35% in losses in transmission ($\eta_t$)[16] . For Europe use 0.05%[17] as default or use EU country values found in (Inogate, 2015)[18].<br>Otherwise Use GREET model to estimate a pipeline loss EF[19]. |
| **Distribution** | Use default of 0.16% losses in distribution system ($\eta_d$)[20]. EU country distribution losses values can be found in (Inogate, 2015)[21]. |

[13] *[pr]* production, is calculated excluding non-energy uses and expressed in energy content. All other volumes *[Ro]*, *[tpi]*, *[tpopi]* and *[Sales]* are also expressed in energy.
[14] Where associated gas is also produced, allocation of emissions between Oil and Gas shall be done using the co-product displacement method.
[15] Companies are welcome to engage with their suppliers and request if they have supplier specific information about the gas they provide for each region. If supplier data is used its shall be documented in the methodology, with a brief explanation of how it has been derived.
[16] Zimmerle *et al.*, 2015, report on a $CH_4$ measurement campaign to detect leakage from Natural Gas Transmission and Storage System in the United States, concluding that methane loss corresponds to a rate of 0.35% of the methane transported by the Transmission and Storage sector in the USA.
[17] Marcogas, 2018, pp. 5.
[18] Inogate, 2015, pp. 122, use 2012 values.
[19] GREET emission factors might be expressed in MJ.km in which case companies shall document the distances their products travel between production and refinery for each geography.
[20] Lamb *et al.*, 2015 report on a $CH_4$ measurement campaign to detect leakage from distribution systems in USA. They conclude that their "new estimate represents 0.10% to 0.22% of the CH4 delivered via the distribution system". We have taken the middle number of this range as representative of methane leakage system, while acknowledging that this can vary substantially based on age, miles of network, pipe materials, maintenance practices and other practices.
[21] Inogate, 2015, pp. 127, use 2012 values.

| Table D.Gas.3 – Full upstream Emission Factors for 3rd party gas | | |
|---|---|---|
| **Country/Region** | **Value** | **Reference and comments** |
| Global average | 16.09 $gCO_2e/MJ$ | IEA, 2018 reports in Figure 11.1 emissions intensities of oil and gas supply globally, differentiating between oi and gas. It reports a total figure of 98.46 $kgCO_2e/boe$, which was converted to $gCO_2e/MJ$. IEA values vary from as low as 10.03 (1.68) to as high as >300 (49.03) $kgCO_2e/boe$ ($gCO_2e/MJ$). |
| Global average | 13.4 $gCO_2e/MJ$ (HHV) | Balcombe *et al.* (2015)[22] estimate that the total supply chain emissions are within the range of 2.7–32.8 g $CO2_e$/ MJ HHV with a central estimate of 13.4 g $CO_2e/MJ$ HHV, if modern equipment with appropriate operation and maintenance regimes is used. |
| China | 15.5 $gCO_2e/MJ$ | Gan *et al.* (2020) estimate an average GHG intensity of domestic gas supply of 15.5 gCO2e/MJ, but with a high variability in a range between 6.2 to 38.9 g $CO_2e/MJ$. |

Companies shall use net volumes for calculations and adjust the energy delivered to secondary energy. In the case of Natural Gas, this implies measuring Natural Gas effectively delivered to pipelines, which might need the following adjustments, depending on where the net volume of the company is set.

| Table D.Gas.4 – Energy calculations for the Gas supply chain | |
|---|---|
| **Net volume** | **Conversion calculations** |
| Production | No adjustment needed. |
| Marketing | Adjust for Transmission and Distribution ($\eta_{t,d}$) losses by using default factors in Table D.Gas.2. |

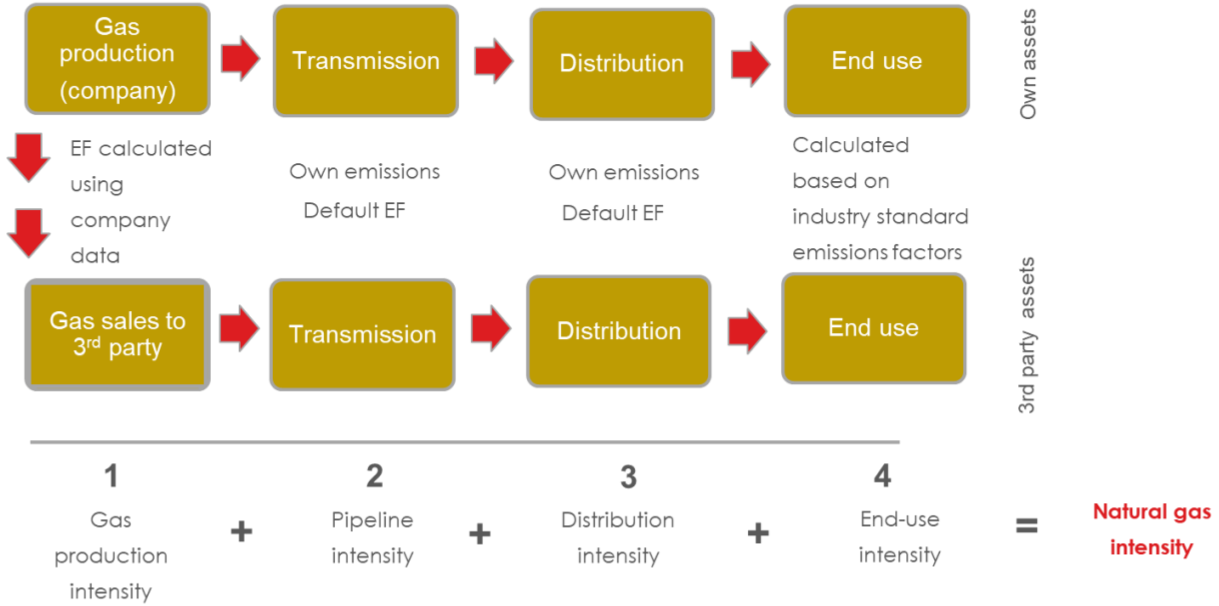
The final WTW carbon intensity of the natural gas product portfolio for a company where the net volume is set downstream will be:

$$CI_{NatGas} = \frac{\left[pr * \left(EF_{pr} + EF_{pp}\right) + tpg * EF_{Up}\right] + Sales * \left(EF_{Distr} + EF_{Fuel}\right)}{\frac{Sales}{(1 - \eta_t - \eta_d)}}$$

The following figures show examples of different configurations depending on which segment defines the net volume. A note that transmission is often a country monopoly under concession. These companies configure pure gas pipeline operators and are excluded from the scope of the methodology and guidance and for this reason are not shown.

[22] See https://www.sustainablegasinstitute.org/wp-content/uploads/2015/09/SGI_White_Paper_methane-and-CO2-emissions_WEB-FINAL.pdf?noredirect=1

*Net volume Upstream*

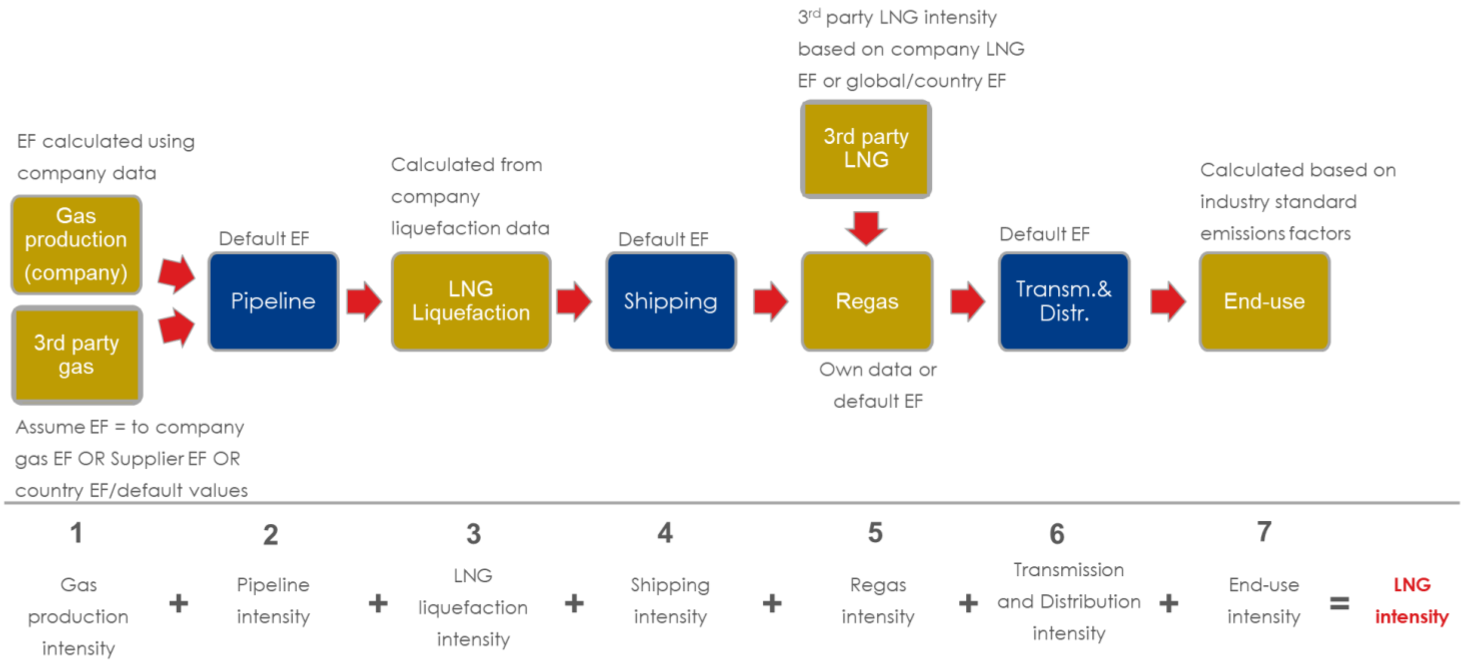



The final WTW carbon intensity of the natural gas product portfolio for a company where the net volume is set upstream will be:

$$CI_{NatGas} = \frac{[pr * (EF_{pr} + EF_{pp} + EF_{Distr} + EF_{Fuel})]}{pr}$$

### *LNG*

The next figure[23] shows the steps of the LNG supply-chain that shall (light brown) and should (blue) be considered for the calculation of the Well-to-Wheel GHG intensity of LNG.




Companies can operate at different steps of this value chain but, in principle, this method is applicable for companies that own or operate LNG facilities. In this case, they may or may not sell their own gas to their own facilities, but in all cases they shall consider the net volumes destined for LNG.

The calculation of the final carbon intensity of the gas delivered will be an average of own gas throughput through own assets, using company-specific emission factors and bought products and/or services using non-company specific emission factors. Companies should use their own natural gas and LNG production emissions data but may use default factors referenced in tables D.LNG.1 to D.LNG.2.

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[23] This figure considers a company where the downstream marketing segment sets its net volume.

| Table D.LNG.1 – Emission calculations for the LNG supply chain | | | | |
|---|---|---|---|---|
| **Step** | **Activity data** | **Emission factors** (GHG intensity of) | **EF Source** | **Emissions calculation** |
| *Upstream activities* | | | | |
| 1a | Own gas sent to LNG production *[pr]* | Gas produced ($gCO_2e/MJ$) *[$EF_{pr}$]* | Own emissions data | *[pr] * [$EF_{pr}$]* |
| 1b | Third party gas *[tpg]* | Gas produced ($gCO_2e/MJ$) *[$EF_{tpg}$]* | Supplier data<br>Default emission factor | *[tpg] * [$EF_{tpg}$]* |
| 2 | Gas transportation *[prLNG]* | Gas transportation in pipeline ($gCO_2e$/GJ.km) [$EF_{pp}$] | Own emissions data<br>Use GREET model to estimate an EF[24]. See table D.Gas.2. | *[pr]* [$EF_{pp}$]*<br>*[tpg]* [$EF_{pp}$]* |
| 3 | LNG liquefaction *[prLNG]* | Carbon intensity of liquefaction process ($tCO_2e$/tLNG) [$EF_{LNG}$] | Own emissions data.<br>Use a world average of 0.25 $tCO_2e$/tLNG[25] | *[prLNG] * [$EF_{LNG}$]*<br>*{prLNG=pr+tpg}* |
| 4 | LNG Shipping *[prLNG]* | Carbon intensity of shipping [$EF_{ship}$] including methane slip | Own data or Supplier data<br>Default factors can be obtained from (API, 2015), Table 15, pp.65 for different transportation modes and vehicles | *[prLNG *[$EF_{ship}$]* |
| 1-4 | 3rd party LNG [*tpLNG*] | Full upstream carbon intensity of third party LNG [*$EF_{UpLNG}$*] | Supplier data<br>Use global default value. See Table D.LNG.2. | *[tpLNG]* [$EF_{UpLNG}$]* |
| *Midstream activities* | | | | |
| 5 | Regasification *[Sales[26]]* | Carbon intensity of regasification [$EF_{regas}$] | Own data<br>Consider 0.0173 tCO2e/tLNG from electricity consumption + 0.09% gas losses ($CH_4$)[27] | *[Sales]* [$EF_{regas}$]* |
| 6a | Gas Transmission | Gas transportation in pipeline ($gCO_2e$/GJ.km) [$EF_{ppt}$] | Use GREET model to estimate transmission grid loss EF[28]. | *[Sales]* [$EF_{ppt}$]* |
| *Upstream activities* | | | | |
| 6b | Gas Distribution *[Sales]* | Gas distribution network ($gCO_2e$/GJ) [$EF_{distr}$] | Use country gas distribution losses emission factors.<br>See table D.Gas.2. | *[Sales]* [$EF_{distr}$]* |
| 7 | End use [*Sales*] | Combustion of fuels [$EF_{fuel}$] | Own data<br>Use (IPCC,2006) value of 56.1 $tCO_2$/TJ | *[Sales]* [$EF_{fuel}$]* |

[24] GREET emission factors might be expressed in MJ.km in which case companies shall document the distances their products travel between production and refinery for each geography.

[25] Computed from several sources by CDP. See file "LNG EF calculation.xls".

[26] Sales are sales of LNG.

[27] As referenced by Shell (2020).

[28] GREET emission factors might be expressed in MJ.km in which case companies shall document the distances their products travel between production and refinery for each geography.

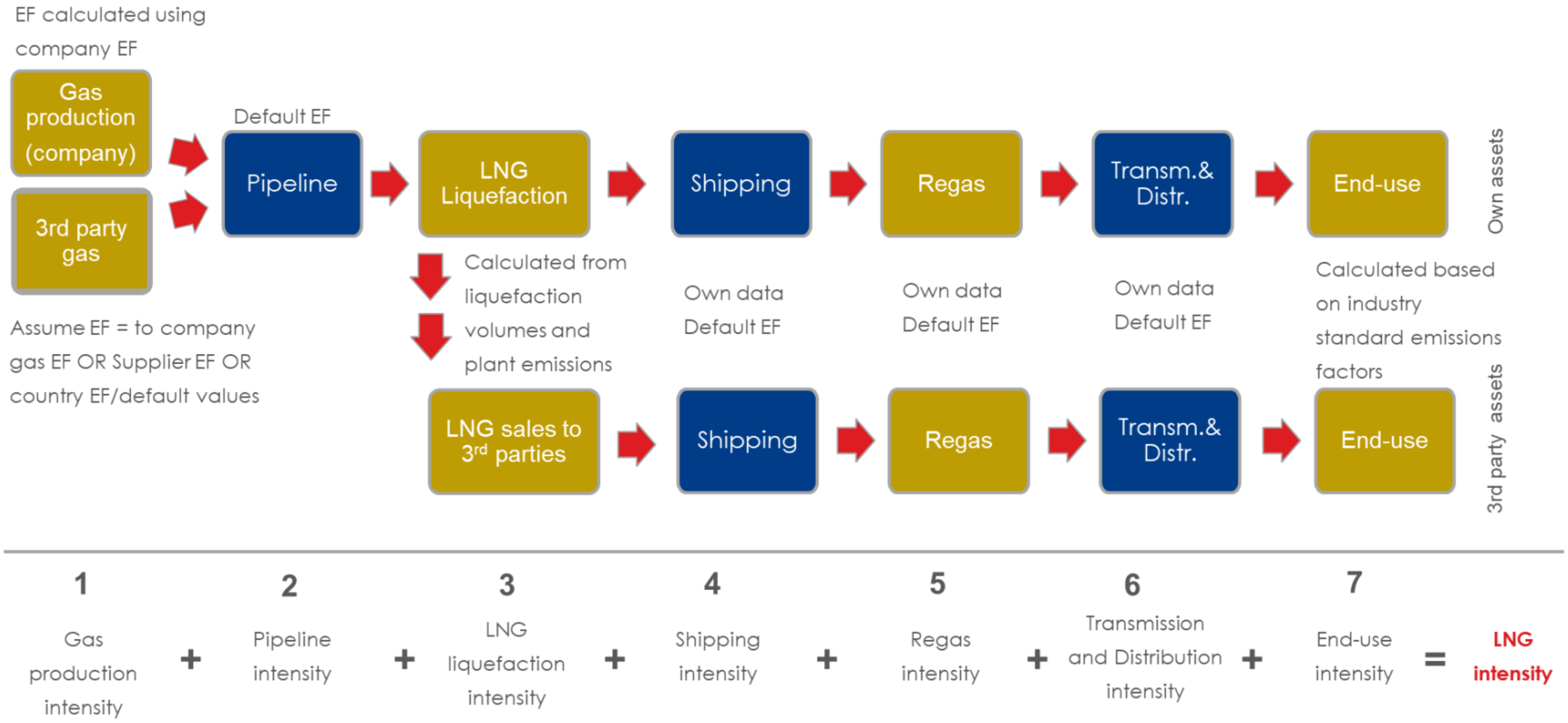
| Table D.LNG.2 – Emission Factors for 3rd party LNG (Well to Tank) | | | | | | |
|---|---|---|---|---|---|---|
| **Country/Region** | **Gas production, processing and pipeline transport** | **Gas liquefaction (incl. purification)** | **LNG carrier transport** | **LNG terminal operations and maritime bunkering** | **Total Value** | **Reference and comments** |
| Global average | 6.1 | 9.2 | 2.5 | 0.7 | 18.5 | Thinkstep (2019), pp. 29 |
| Global average | | | | | 21.2 | ICCT (2020), pp. 27 |
| USA | | | | | 19.7 | Lindstad and Rialland (2020) |
| Europe | | | | | 19.9 | Lindstad and Rialland (2020) |
| Australia–Asia | | | | | 22.0 | Lindstad and Rialland (2020) |
| North America | 8.1 | 8.2 | 1.9 | 0.7 | 18.9 | Thinkstep (2019), pp. 140 |
| Europe | 7.4 | 10.2 | 2.5 | 0.7 | 20.9 | Thinkstep (2019), pp. 140 |
| Asia Pacific | 5.9 | 9.0 | 2.4 | 0.7 | 18.0 | Thinkstep (2019), pp. 140 |
| China | 5.1 | 8.9 | 2.6 | 0.7 | 17.3 | Thinkstep (2019), pp. 140 |
| Middle East | 5.3 | 9.5 | 2.6 | 0.7 | 18.2 | Thinkstep (2019), pp. 140 |

Considering the level of losses involved, companies do not need to adjust LNG energy delivered to secondary energy - which would imply measuring Natural Gas effectively delivered to pipelines – and can use LNG production for that purpose.

The final WTW carbon intensity of the LNG product portfolio for a company where the net volume is set downstream will be:

$$CI_{LNG} = \frac{\left[pr * \left(EF_{pr} + EF_{pp}\right) + tpg * \left(EF_{pr} + EF_{pp}\right)\right] + \left[pr_{LNG} * \left( EF_{LNG} + EF_{ship}\right)\right] + \left[tp_{LNG} * EF_{UpLNG}\right] + \left[Sales * \left(EF_{regas} + EF_{ppt} + EF_{distr} + EF_{Fuel}\right)\right]}{Sales\{= pr_{LNG} + tp_{LNG}\}}$$

*Net volume Upstream*

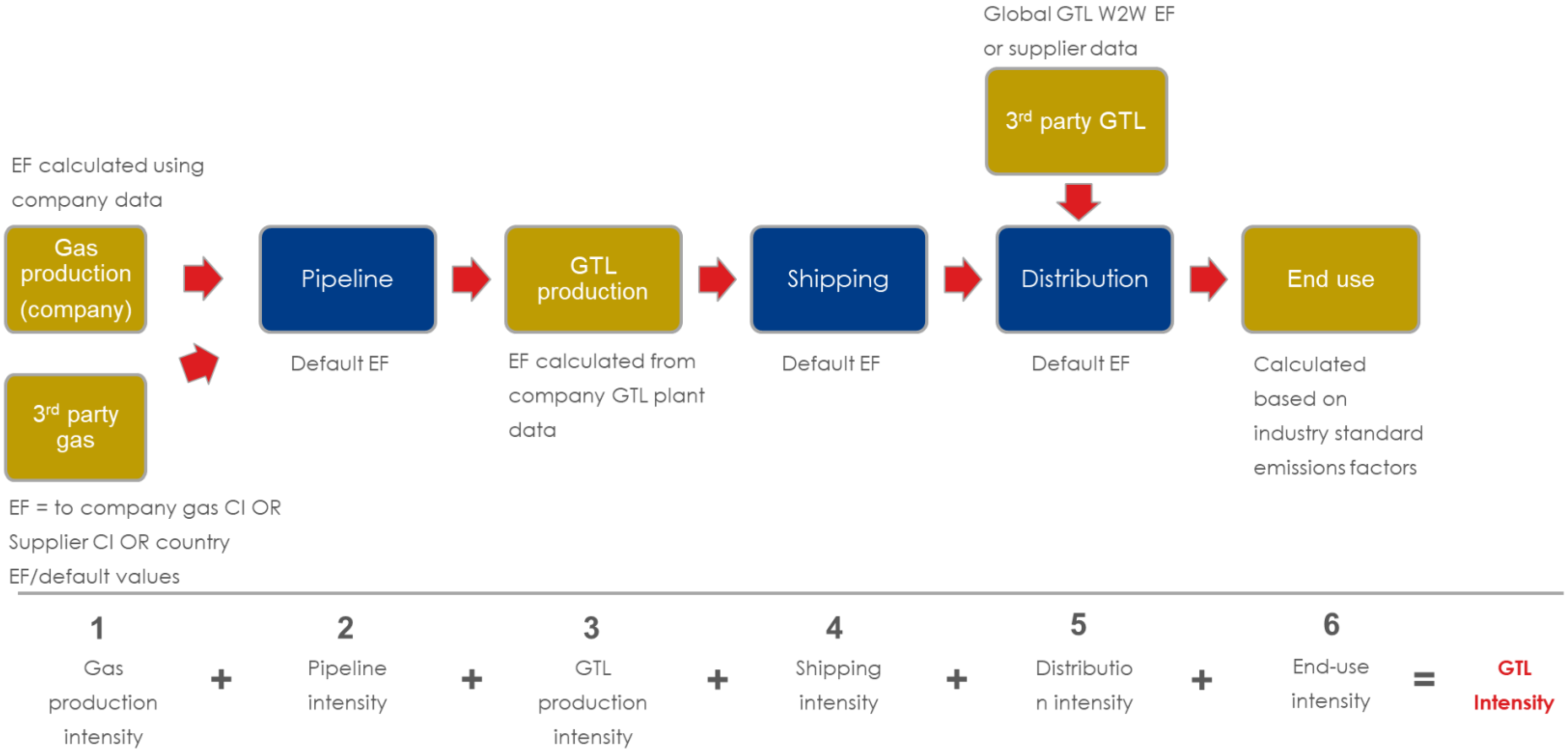



The final WTW carbon intensity of the LNG product portfolio for a company where the net volume is set upstream (by LNG production) will be:

$$CI_{LNG} = \frac{[pr * (EF_{pr} + EF_{pp}) + tpg * (EF_{tpg} + EF_{pp})] + [pr_{LNG} * (EF_{LNG} + EF_{ship} + EF_{regas} + EF_{ppt} + EF_{Distr} + EF_{Fuel})]}{pr_{LNG}}$$

## *GTL*

The next figure shows the steps of the GTL supply-chain that shall (light brown) and should (blue) be considered for the calculation of the Well-to-Wheel GHG intensity of GTL[29].




Companies can operate at different steps of this value chain but, in principle, this method is applicable for companies that own or operate GTL facilities. Companies that market GTL should ask their suppliers for information about the carbon intensity of their fuel or can use a W2W emission factor for GTL.

[29] This figure considers a company where the downstream marketing sets its net volume.

The calculation of the final carbon intensity of the GTL delivered will be an average of own gas throughput through own assets, using company-specific emission factors and bought products and/or services using non-company specific emission factors. Companies that produce GTL and distribute it should use their own natural gas and GTL production emissions data but may use default factors referenced in tables D.GTL.1 to D.GTL.2.

**Table D.GTL.1 – Emission calculations for the GTL supply chain**

| Step | Activity data | Emission factors (GHG intensity of) | EF Source | Emissions calculation |
|---|---|---|---|---|
| *Upstream activities* | | | | |
| 1a | Own gas sent to GTL production *[pr]* | Gas produced ($gCO_2e/MJ$) *[$EF_{pr}$]* | Own emissions data | *[pr] * [$EF_{pr}$]* |
| 1b | Third party gas *[tpg]* | Gas produced ($gCO_2e/MJ$) *[$EF_{tpg}$]* | Own emissions data or supplier data<br>Default emission factor | *[tpg] * [$EF_{tpg}$]* |
| 2 | Gas transported *[pr]* | Gas transportation in pipeline ($gCO_2e/GJ.km$) [$EF_{pp}$] | Own emissions data<br>Use GREET model to estimate an EF[30]. See table D.Gas.2. | *[pr]* [$EF_{pp}$]*<br>*[tpg] * [$EF_{pp}$]* |
| *Midtstream activities* | | | | |
| 3 | GTL production *[prGTL]* | Carbon intensity of GTL production ($tCO_2e/tGTL$) [$EF_{GTL}$] | Own emissions data. | *[prGTL] * [$EF_{GTL}$]* |
| 1-3 | 3rd party gas inputs *[tpg]* | Full upstream EF of gas produced ($gCO_2e/MJ$) [$EF_{Up}$] | Supplier data[31]<br>Use IEA global value as default. See table D.Gas.3. | *[tpg] * [$EF_{Up}$]* |
| 4 | GTL Shipping quantity *[prGTL]* + distance [$Dist_{GTL}$] | Carbon intensity of shipping [$EF_{ship}$] | Own data or Supplier data<br>Default value of 0.23 gCO2e/MJ.1000km[32] | *[prGTL]* [$Dist_{GTL}$]*[$EF_{ship}$]* |
| *Downstream activities* | | | | |
| 5 | Distribution *[$pr_{GTL}$]* | Distribution network ($gCO_2e/MJ$) [$EF_{distr}$] | Own data or supplier data<br>Default value of 1 $gCO_2e/MJ$ of delivered fuel[33] | *[$pr_{GTL}$]* [$EF_{distr}$]* |
| 7 | End use [*Sales*] | Combustion of fuels [$EF_{fuel}$] | Own data<br>Default value of 71.98 gCO2e/MJ[34] | *[Sales]* [$EF_{fuel}$]* |
| 1-7 | End use [*Sales*] | WtW emission factor for GTL [$EF_{WTW-GTL}$] | Use supplier data<br>Use default value of 94.3 $gCO_2e/MJ$[35] | *[Sales]*[$EF_{WTW-GTL}$]* |

[30] GREET emission factors might be expressed in MJ.km in which case companies shall document the distances their products travel between production and refinery for each geography.

[31] Companies are welcome to engage with their suppliers and request if they have supplier specific information about the gas they provide for each region. If supplier data is used its shall be documented in the methodology, with a brief explanation of how it has been derived.

[32] Joint Research Council, European Commission (2014), WELL-TO-TANK Report Version 4.a, JEC WELL-TO-WHEELS ANALYSIS, section 3.1.4, pp. 29.

[33] As provided by Shell in its NCF methodology, based on GREET 2018 model for a GTL tanker.

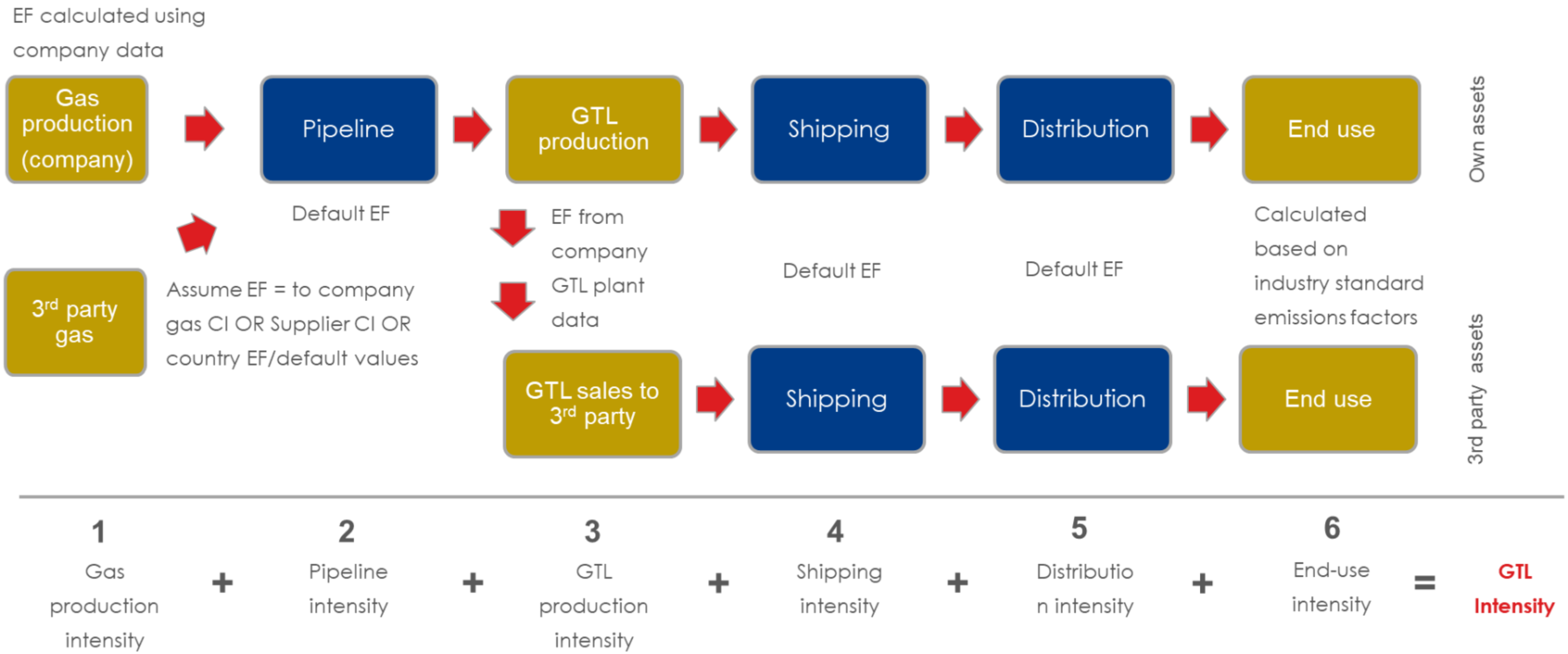
[34] As provided by Shell in its NCF methodology, based on GREET 2018 model for a GTL tanker.

[35] As per "WELL-TO-TANK Appendix 2 - Version 4a - Summary of energy and GHG balance of individual pathway", pp.18, line 1 of Table 1.5 Synfuels.

The final WTW carbon intensity of the GTL product portfolio for a company where the net volume is set downstream will be:

$$CI_{GTL} = \frac{[pr * (EF_{pr} + EF_{pp}) + tpg * (EF_{pr} + EF_{pp})] + [pr_{GTL} * (EF_{GTL} + Dist_{GTL} * EF_{ship})] + [tp_{GTL} * EF_{UpGTL}] + [Sales * (EF_{distr} + EF_{Fuel})]}{Sales\{= pr_{GTL} + tp_{GTL}\}}$$

*Net volume Upstream*

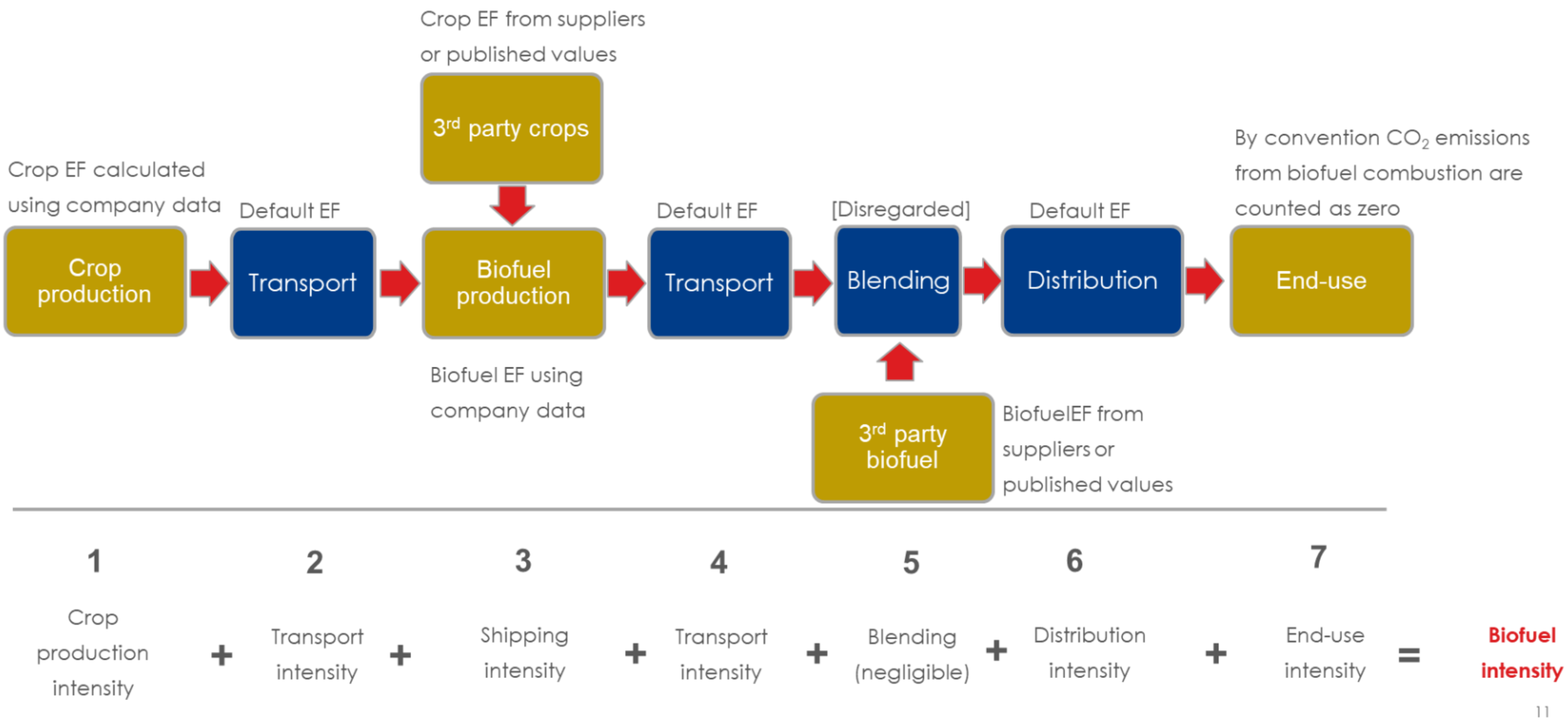



The final WTW carbon intensity of the GTL product portfolio for a company where the net volume is set midstream (GTL production) will be:

$$CI_{GTL} = \frac{[pr * (EF_{pr} + EF_{pp}) + tpg(EF_{Up} + EF_{pp})] + [pr_{GTL} * (EF_{GTL} + Dist_{GTL} * EF_{Ship} + EF_{distr} + EF_{Fuel})]}{Sales\{= pr_{GTL}\}}$$

### *Biofuels*

The next figure shows the steps of the biofuel supply-chain that shall (light brown) and should (blue) be considered for the calculation of the Well-to-Wheel GHG intensity of biofuels.




The calculation of the final carbon intensity of the biofuel delivered will be an average of own throughput through own assets, using company-specific emission factors and bought products and/or services using non-company specific emission factors.

| Table D.Bio.1 – Emission calculations for the GTL supply chain | | | | |
|---|---|---|---|---|
| **Step** | **Activity data** | **Emission factors** (GHG intensity of) | **EF Source** | **Emissions calculation** |
| *Upstream (crop production)* | | | | |
| 1 | Crop production *[$pr_{crop}$]* | Crop produced intensity ($gCO_2e/MJ$) *[$EF_{prcrop}$]* | Own emissions data<br>For LUC emissions see Table D.Bio.2, column 1 | *[$pr_{crop}$] * [$EF_{prcrop}$]* |
| 2 | Crop transport [*$pr_{crop}$*] | Crop transportation ($kgCO_2e/GJ$) [$EF_{tr}$] | Own emissions data<br>Default values for transport, see Table D.Bio.2, column 2. | *[$pr_{crop}$] * [$EF_{tr}$]* |
| 1-2 | 3rd party crops *[tpcrop]* | Crop production EF ($gCO_2e/MJ$) [$EF_{tpcrop}$] | Supplier data[35]<br>Use EF per crop and region, e.g. OECD | *[tpcrop] * [$EF_{tpcrop}$]* |
| *Midstream (biofuel production and blending)* | | | | |
| 3 | Biofuel production *[$pr_{Bio}$]* | Biofuel production intensity [$EF_{pBio}$] | Own emissions data | *[$pr_{Biofuel}$])* [$EF_{pBio}$]* |
| 4 | Biofuel transport [$Dist_{Bio}$] | Biofuel transportation ($kgCO_2e/GJ.km$) [$EF_{tr}$] | Own emissions data<br>Default values for transport. See Table D.Bio., column 2. | *[$pr_{Bio}$]* [$Dist_{Bio}$]*[$EF_{tr}$]* |
| 5 | Blending (Due to its small overall emissions, this step is not considered in the methodology). Likewise, the blended product is not considered, only the biofuel fraction of the blended product, | | | |
| *Downstream (marketing of biofuels)* | | | | |
| 1-5 | 3rd party biofuels *[$tp_{Bio}$]* | Biofuel production intensity [$EF_{tpBio}$] | Supplier data[36]<br>Use EF per biofuel and crop, e.g. see OECD, 2019, Annex 5A2 | *[$tp_{Bio}$]** [$EF_{tpBio}$] |
| 6 | Distribution *[$pr_{Bio}$]*[37] | Distribution ($gCO_2e/GJ$) [$EF_{distr}$] | Own data or supplier data<br>Default value of 1 $gCO_2e/MJ$ of delivered fuel[38] or biofuel specific as per See Table D.Bio.2, column 3. | *[$pr_{Bio}$]** [$EF_{distr}$]<br>*[$tp_{Bio}$]** [$EF_{distr}$] |
| 7 | End use [*$Sales_{Bio}$*] | Combustion of fuels [$EF_{fuel}$] | Default value of 0 $gCO_2/MJ$[39] | [*$Sales_{Bio}$*]* [$EF_{fuel}$] |

[36] Companies are welcome to engage with their suppliers and request if they have supplier specific information about the crops they provide. If supplier data is used its shall be documented in the methodology, with a brief explanation of how it has been derived.

[37] Liquid biofuels are usually blended with fossil fuels to produce a graded fuel blend. This is the product that will be distributed - composed of liquid petroleum products + biofuels. The liquid petroleum products have already been considered (volume wise) in the Oil section - for this reason only the biofuel part is considered here and not the blend volume.

[38] Joint Research Council, European Commission (2014), WELL-TO-TANK Report Version 4.a, JEC WELL-TO-WHEELS ANALYSIS, section 3.1.4, pp. 29.

[39] In the case of biofuels, the carbon is of non-fossil origin and the $CO_2$ emissions are classified as biogenic and not reported under the same category as fossil carbon. For that reason, the fossil carbon EF is zero and only CH4 and NOx may be considered. However, due to the complexity of calculating $CH_4$ and NOx for biofuel use – where both duel type and combustion equipment can vary widely – it is not proposed this to be calculated by the company.

| Table D.Bio.2 – Emission factors for selected biofuels | | | |
|---|---|---|---|
| **Biofuel type and origin** | **LUC emissions**[40] | **Transportation to market** [41] | **Distribution**[35] |
| | gCO2/MJ | (g $CO_2$e/MJ final fuel) | |
| Ethanol from sugar beet | 15 | 3.8 | 1.6 |
| Ethanol from wheat | 34 | 1.0 | 1.6 |
| Ethanol from Barley/Rye | 36 | 1.1 | 1.6 |
| Ethanol from Maize | 14 | 0.9 | 1.6 |
| Ethanol from corn | | 0.5 | 5.2 |
| Ethanol from sugar cane (Brazil) | 17 | 6.7 | 1.6 |
| Biodiesel | | - | 1.4 |
| Biodiesel (HVO) | 101 | 0.5 | 1.3 |
| Biodiesel (HVO), imported oil | | 3.3 | 1.3 |
| Biodiesel sunflower | 63 | | |
| Biodiesel palm oil | 231 | | |
| Biodiesel rapeseed | 65 | | |
| Biodiesel soybean | 150 | | |

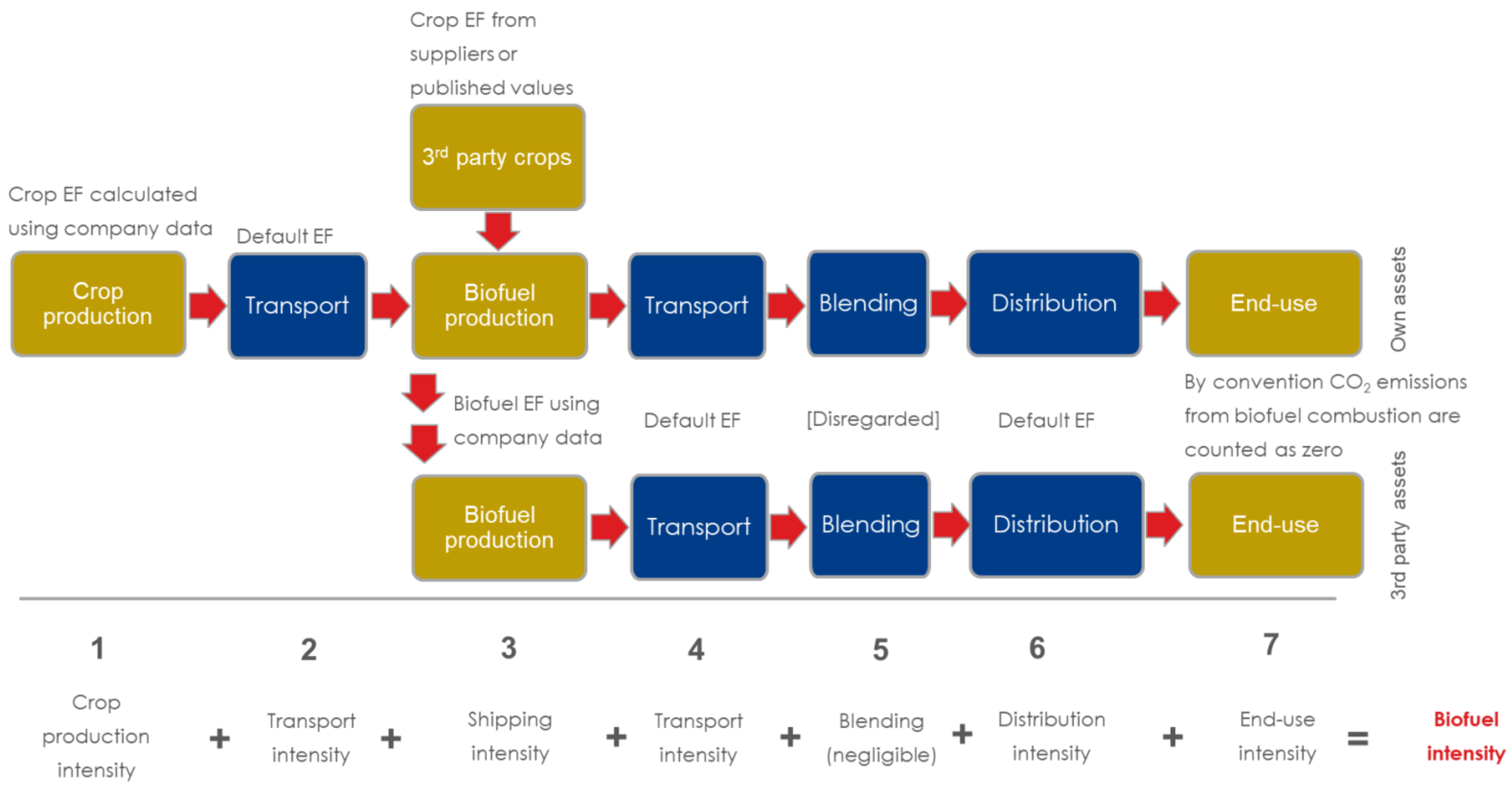
The final WTW carbon intensity of biofuels portfolio for a company where the net volume is set downstream will be:

$$CI_{Bio} = \frac{[pr_{crop} * (EF_{prcrop} + EF_{tr}) + tpcrop(EF_{tpcrop})] + [pr_{Bio} * (EF_{pBio} + Dist_{Bio} * EF_{tr} + EF_{distr}) + tp_{Bio} * (EF_{tpBio} + EF_{distr})]}{Sales\{= pr_{Bio} + tp_{Bio}\}}$$

40 Ecofys, 2015

41 Selected values from Joint Research Council, European Commission (2014), WELL-TO-TANK Report Version 4.a, JEC WELL-TO-WHEELS ANALYSIS, pp. 12 and 15.

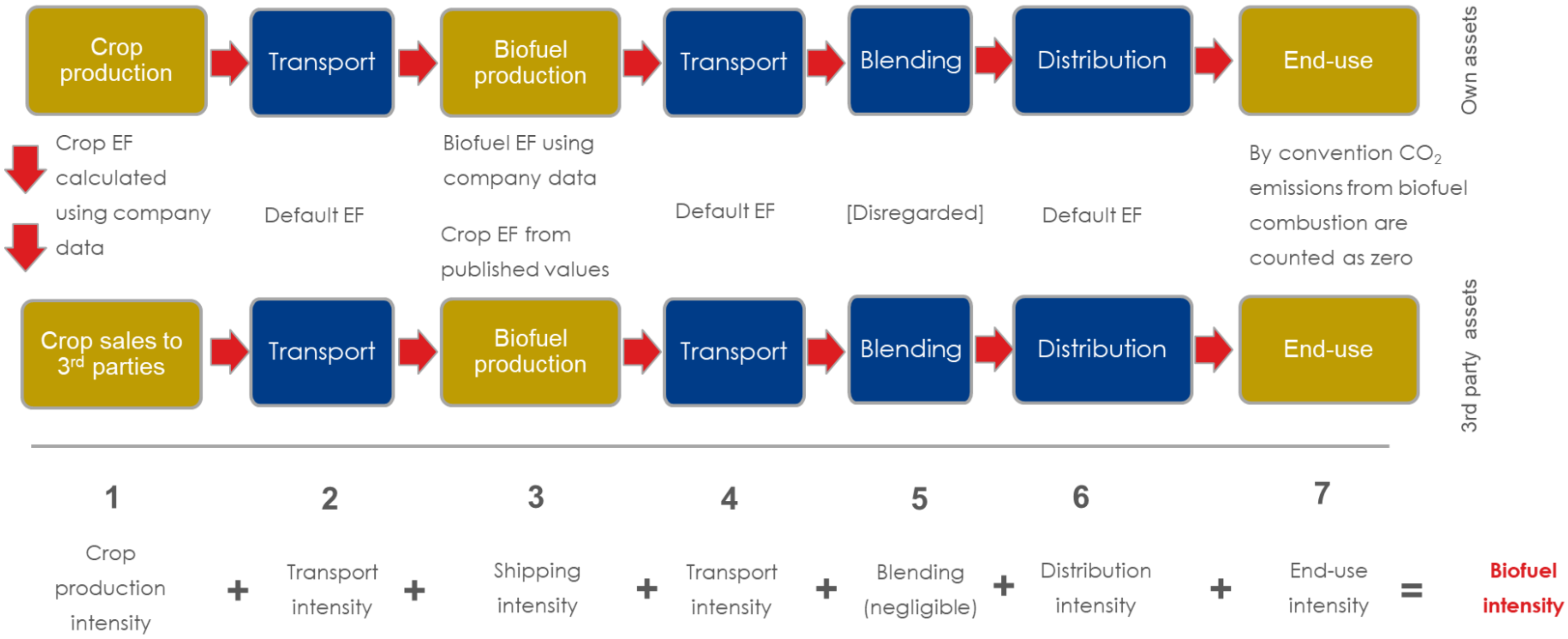
*Net volume Midstream*




The final WTW carbon intensity of biofuels portfolio for a company where the net volume is set midstream (biofuel production) will be:

$$CI_{Bio} = \frac{[pr_{crop} * (EF_{prcrop} + EF_{tr}) + tpcrop(EF_{tpcrop})] + [pr_{Bio} * (EF_{pBio} + Dist_{Bio} * EF_{tr} + EF_{distr})]}{Sales\{= pr_{Bio}\}}$$

*Net volume Upstream*

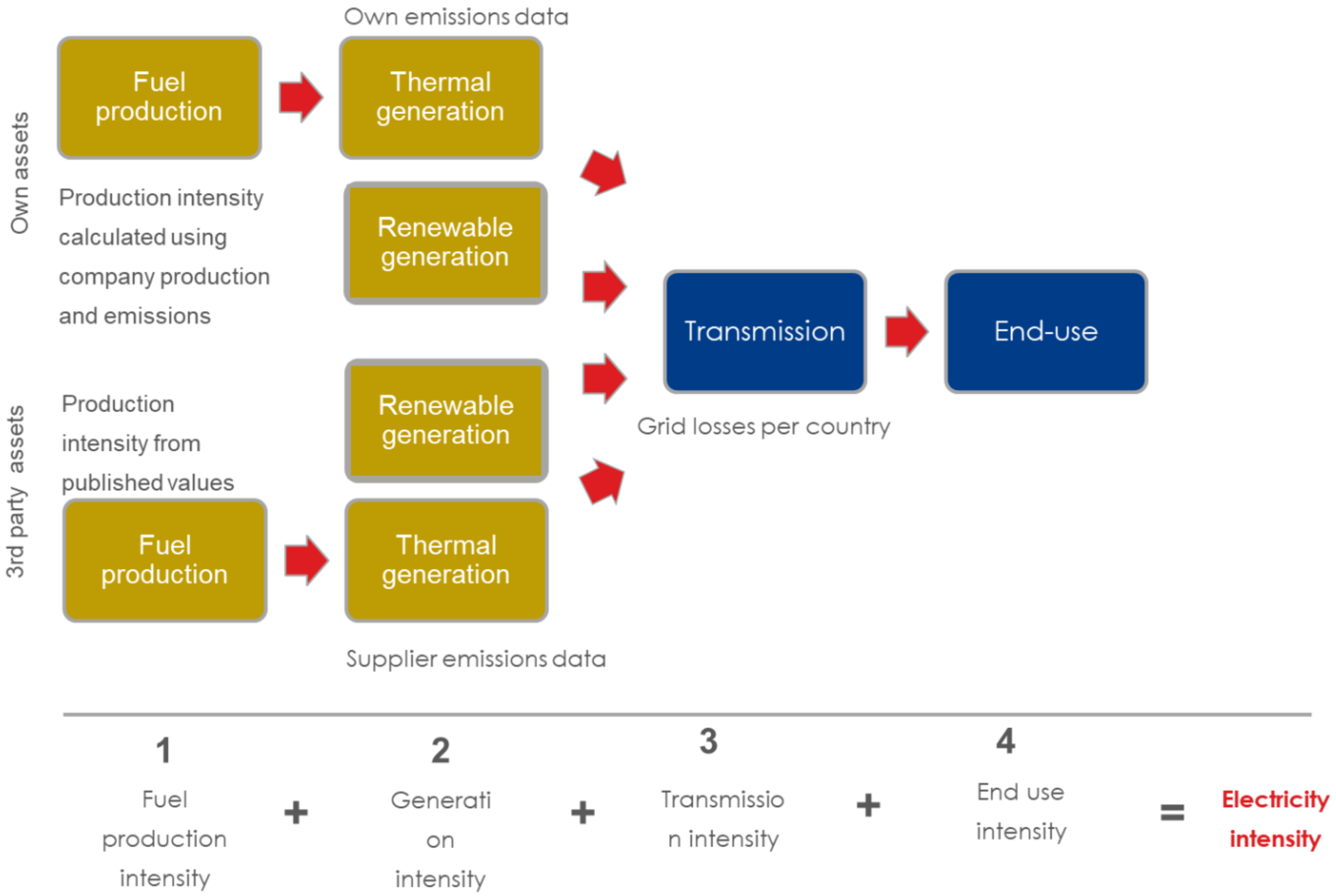



The final WTW carbon intensity of biofuels portfolio for a company where the net volume is set upstream will be:

$$CI_{Bio} = \frac{[pr_{crop} * (EF_{prcrop} + EF_{tr})] + [pr_{Bio} * (EF_{pBio} + Dist_{Bio} * EF_{tr} + EF_{distr})]}{Sales\{= pr_{Bio}\}}$$

## *Electricity*

The next figure[42] shows the steps of the electricity supply-chain that shall (light brown) be considered for the calculation of the Well-to-Wheel GHG intensity of electricity.




[42] This figure is made considering a company where the downstream marketing segment is the main one (the ones that sets its net volume).

In the case of electricity a distinction is made between the electricity sold to final end-user (Electricity sold) and the electricity produced through own assets (Electricity produced) which, in turn, can be produced from “renewable generation” or “thermal generation”. The following rules apply for each of these:

- For own thermal generation, the emissions generated in the production of the electricity in own assets shall be used, to which should be added the emissions related to fuel production, which can be computed using the methods highlighted in previous sub-chapters to this annex;
- Renewable generation from own assets shall be accounted at zero carbon intensity;
- Purchased electricity from others, shall take into consideration the type of generation, being that:
    - Renewable generation shall be accounted at zero carbon intensity;
    - Thermal generation should be accounted considering the supplier emission factor for that generation type, but may be at carbon intensity of that specific type of generation for the specific grid from which electricity is sourced.

In all markets where Market Instruments (e.g. RECs, GO’s) exist, the company purchases of renewable electricity (e.g. through PPA’s) shall comprise bundled electricity (electricity + instruments) and the company shall retire the instruments on behalf of their clients. Company purchases of electricity shall be taken as “net purchases”, which means that if a company produces more than what it sells to final consumers, its purchased volume shall be taken as zero; if a company sells more than what it produces, its purchased volume shall be equal to sales minus production.

Emissions from electricity productions will be:

$$CO_{2,Elect} = (EF_{Fuel,upstream} + EF_{Fuel,Use}) * Energy\ Input_{Own\ production} + EF_{Purchased\ elect} * Purchased\ electricity$$

As to the denominator (Energy), electricity shall be accounted in the following way:

- The volumes of own production or [production + net purchases][43] (whichever is largest) of electricity injected to the grid are accounted (grid losses not considered);
- An efficiency factor is defined as $\eta_{elect} = \frac{Electric\ output}{Primary\ Energy\ Input}$ – it considers the amounts of electricity produced relative to the primary energy input into that production - and is applied to the electricity values[44]. This efficiency factor is calculated from the scenario data used

[43] This factor is to take into consideration that companies can have more (or less) production than what they sell at the retail side. In the first case, they might even trade their own production with other retailers but is the net purchase that matters and covers the difference between electricity production and the excess they sell to end consumers. However, sales to consumers reflect grid losses while “net purchases” should reflect quantities injected to the grid.

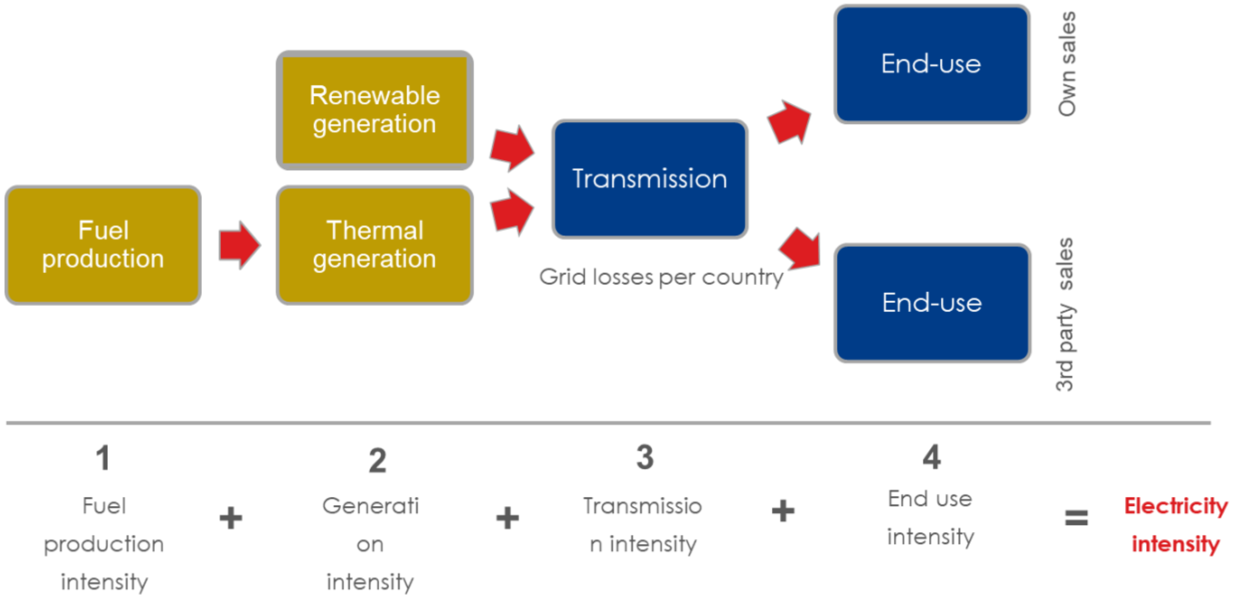
[44] Using this factor is equivalent to using the co-product allocation approach, where renewable electricity is considered to substitute an equal amount of average primary energy used to produce electricity in the grid. This factor will vary year-on-year according to the scenario and will tend to a value close to 1 (value of renewable sources) as the economy decarbonizes.

and is equal to total electricity generation divided by the sum of all energy sources inputs into electricity (coal, oil, gas, nuclear and renewables).

The final WTW carbon intensity of the electricity sales portfolio for a company where the net volume is set downstream (sales) will be:

$$CI_{Elect} = \frac{\left[(EF_{Fuel,upstream} + EF_{Fuel,Use}) * Energy\ Input_{Own\ production} + CI_{Purchased\ elect} * Purchased\ electricity\right]}{(Production + net\ purchases)/_{\eta_{elect}}}$$

*Net volume Upstream (Generation)*




The final WTW carbon intensity of the electricity sales portfolio for a company where the net volume is set Upstream (Electricity generation) will be:

$$CI_{Elect} = \frac{\left[(EF_{Fuel,upstream} + EF_{Fuel,Use}) * Energy\ Input_{Own\ production}\right]}{Production/_{\eta_{elect}}}$$

*Acknowledgments*

This annex relies heavily on Shell's "The Net Carbon Footprint Model: Methodology – Rev.2", April 2020, in particular the supply-chain figures are modified versions of Shell's Figures. We wish to thanks to Shell TWG colleagues for allowing us to use and modify for the purpose of this methodology.

*References*

Jing, L., El-Houjeiri, H.M., Monfort, J. *et al.* Carbon intensity of global crude oil refining and mitigation potential. *Nat. Clim. Chang.* **10,** 526–532 (2020). https://doi.org/10.1038/s41558-020-0775-3

Masnadi,M., El-Houjeiri, H., Schunack, D., Li, Y., Englander, J.E., Badahdah, A., Monfort, J.C., Anderson, J.E., Wallington, T.J., Bergerson, J.A., Gordon, D., Koomey, J., Przesmitzki, S., Azevedo, I.L., Bi, X.T., Duffy, J.E., Heath, G.A., Keoleian, G.A., McGlade, C., Meehan, D.N., Yeh, S., You, F., Wang, M, Brandt, A.R. (2018) "Global carbon intensity of crude oil production", Vol. 361, Issue 6405, pp. 851-853, DOI: 10.1126/science.aar6859

API (2009) API Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Natural Gas Industry, available at https://www.api.org/~/media/files/ehs/climate-change/2009_ghg_compendium.ashx

Lamb, B.K., Edburg†, S.L., Ferrara, T. W., Howard, T., Harrison,M.R., Kolb‖, C.E., Townsend-Small,A., Dyck, W., Possolo,A. and Whetstone, J.R. (2015) "Direct Measurements Show Decreasing Methane Emissions from Natural Gas Local Distribution Systems in the United States", Environ. Sci. Technol. 2015, 49, 8, 5161–5169, March 31, 2015, https://doi.org/10.1021/es505116p

Zimmerle, D.J., Williams,L.L., Vaughn, T.L., Quinn, C., Subramanian, R., Duggan, G.P., Willson, B., Opsomer, J.D., Marchese, A.J., Martinez, D.M. and Robinson, A.L. (2015) "Methane Emissions from the Natural Gas Transmission and Storage System in the United States", Environ. Sci. Technol. 2015, 49, 15, 9374–9383, July 21, 2015, https://doi.org/10.1021/acs.est.5b01669

Balcombe, P., Anderson, K., Speirs, J., Brandon, N. and Hawkes, A. (2015) "METHANE AND CO2 EMISSIONS FROM THE NATURAL GAS SUPPLY CHAIN AN EVIDENCE ASSESSMENT", Imperial College London and Sustainable Gas institute, September 2015, available at https://www.sustainablegasinstitute.org/wp-content/uploads/2015/09/SGI_White_Paper_methane-and-CO2-emissions_WEB-FINAL.pdf?noredirect=1

Marcogaz (2018) “Survey methane emissions for gas transmission in Europe – Update 2017”, available at https://www.marcogaz.org/app/download/7926773063/WG-ME-17-09.pdf?t=1541674874

Inogate (2015) “14.AZ:“ENERGY (ELECTRICITY & GAS) SECTOR PERFORMANCE ASSESSMENT AND IMPROVEMENT UNDER THE REGULATORY PERSPECTIVE”, available at http://www.inogate.org/documents/14_AZ_Regulatory_Treatment_of_Losses_v5_clean.pdf

Shell (2020) “The Net Carbon Footprint Model: Methodology – Rev.2”, April 2020, available at https://www.shell.com/energy-and-innovation/the-energy-future/what-is-shells-net-carbon-footprint-ambition/_jcr_content/par/expandablelist_copy_/expandablesection_49667105.stream/1586968094020/863276ce89c1204cc35997c56925b8f97818b458/the-ncf-methodology-rev.pdf

API (2015) “Liquified Natural Gas (LNG) Operations – Consistent Methodology for Estimating Greenhouse Gas Emissions”, available at https://www.api.org/~/media/Files/EHS/climate-change/api-lng-ghg-emissions-guidelines-05-2015.pdf

Lindstad, E.; Rialland, A. (2020) “LNG and Cruise Ships, an Easy Way to Fulfil Regulations—Versus the Need for Reducing GHG Emissions”, Sustainability 2020, 12, 2080, available at https://www.mdpi.com/2071-1050/12/5/2080

OECD (2019), Enhancing Climate Change Mitigation through Agriculture, OECD Publishing, Paris, https://doi.org/10.1787/e9a79226-en.

Ecofys (2015) “The land use change impact of biofuels consumed in the EU - Quantification of area and greenhouse gas impacts”, available at https://ec.europa.eu/energy/sites/ener/files/documents/Final%20Report_GLOBIOM_publication.pdf

Thinkstep (2019) “Life Cycle GHG Emission Study on the Use of LNG as Marine Fuel”, available at https://www.thinkstep.com/content/life-cycle-ghg-emission-study-use-lng-marine-fuel-1

ICCT (2020) “The Climate Implications of UsingLNGas a Marine Fuel; ICCT, International Council on Clean Transportation”, available at https://theicct.org/publications/climate-impacts-LNG-marine-fuel-2020