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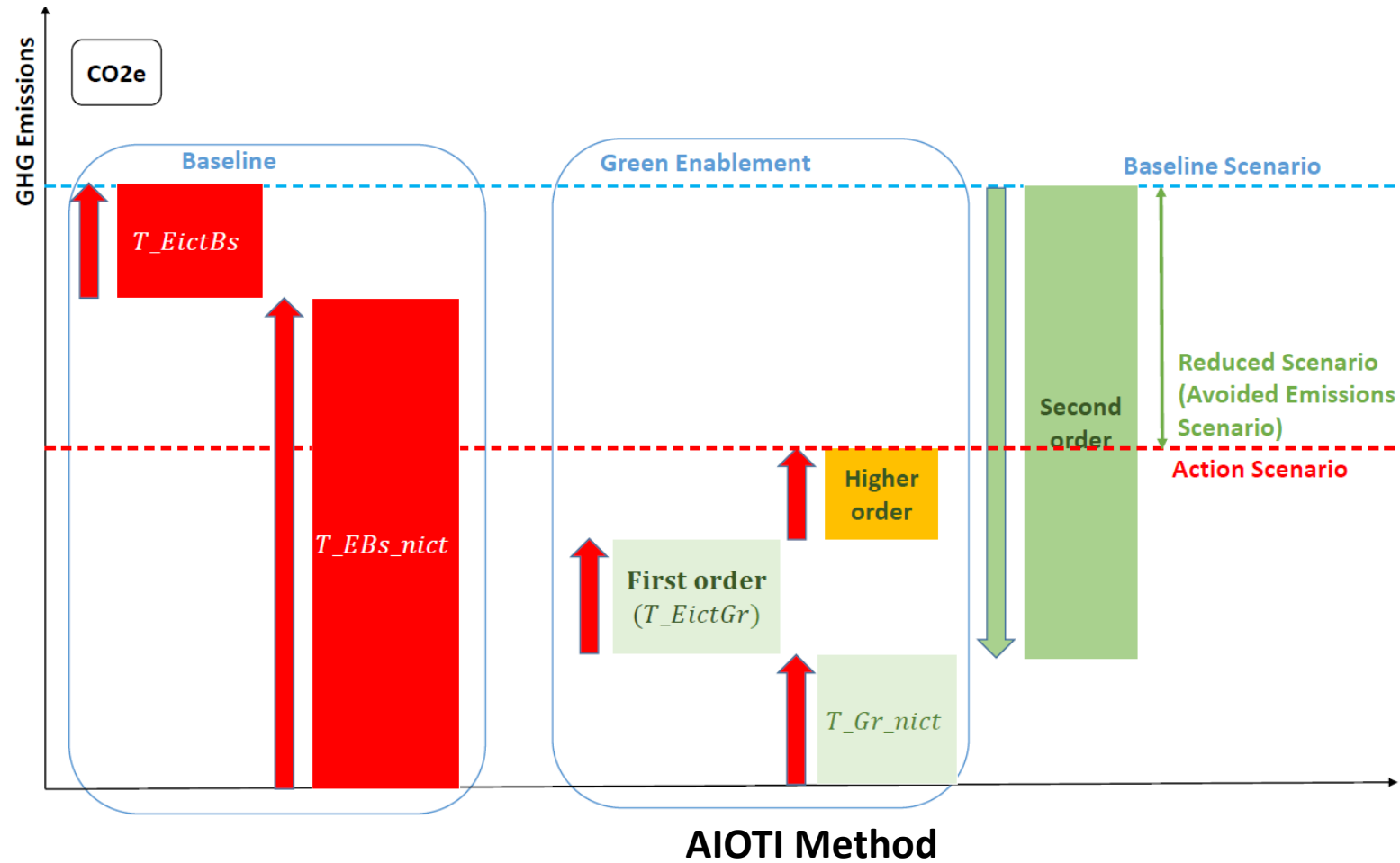
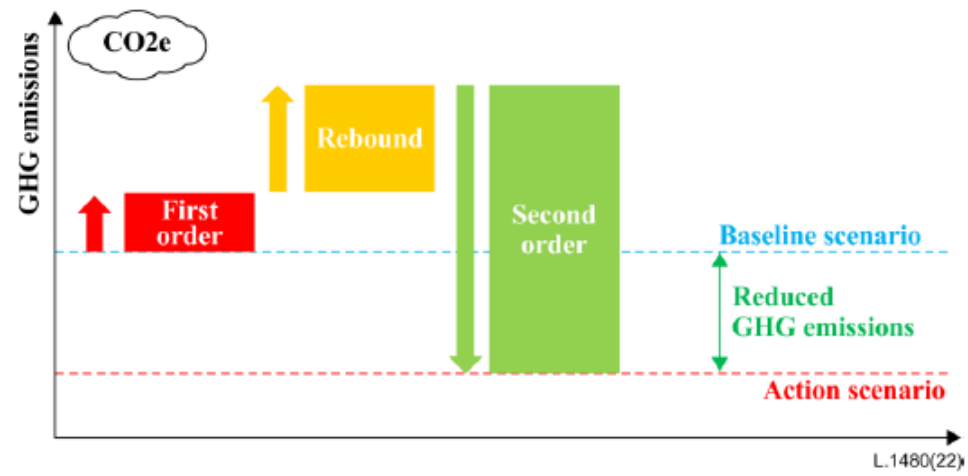
AIOTI method of measuring total avoided carbon emissions in vertical sectors

Georgios Karagiannis, Huawei, AIOTI Chair of WG ICT for CO2 reduction Methodologies

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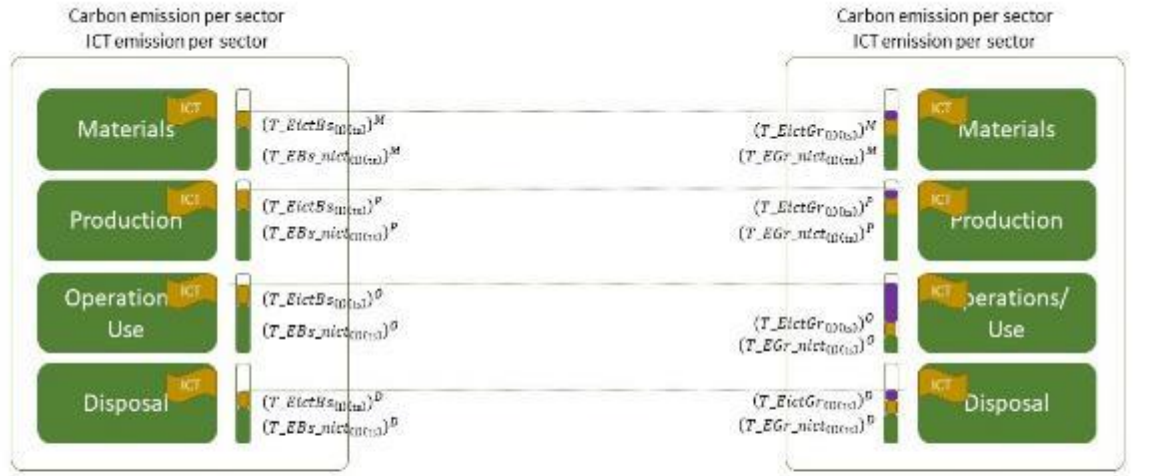
AIOTI method of measuring total avoided carbon emissions in vertical sectors, when applying ICT for non-recycled products



AIOTI method of measuring total avoided carbon emissions in vertical sectors, when applying ICT for non-recycled products

Carbon footprint (Baseline scenario)

Carbon footprint (Green enabled scenario)



$$T_{EBS_nict(t,s)} = \sum_i T_{EBS_nict^i(t,s)}$$

$$T_{EictBs(t,s)} = \sum_i T_{EictBs^i(t,s)}$$

$$T_{EGr_nict(t,s)} = \sum_i T_{EGr_nict^i(t,s)}$$

$$T_{EictGr(t,s)} = \sum_i T_{EictGr^i(t,s)}$$

Total ICT Avoided Carbon Emissions
 $TAE_{ICT(t,s)} = T_{EictBs(t,s)} - T_{EictGr(t,s)}$

Industrial sector carbon emissions, excluding ICT carbon emissions

Total Avoided Carbon Emissions in Industrial Sector

$$TAE_{(t,s)} = (T_{EBS_nict(t,s)} + T_{EictBs(t,s)}) - (T_{EGr_nict(t,s)} + T_{EictGr(t,s)}) - T_{EictRB}$$

Avoided carbon emissions

ICT carbon emissions

- LBs_nict : total number of product/components (m) used in the Baseline scenario, excluding the ICT infrastructure;
- Superscripts M, P, O, D , denote that the carbon emissions calculations are related to the LC phases: Material, Product, Operation, Discard, respectively

- First order effects = $T_{EictGr(t,s)}$
- Second order effects = $T_{EBS_nict(t,s)} + T_{EictBs(t,s)} - T_{EGr_nict(t,s)}$
- Higher order effects = T_{EictRB}

$$T_{EBS_nict^M(t,s)} = \sum_{m=1}^{LBs_nict} EBS_nict^M_{(m)(t,s)}$$

$$T_{EBS_nict^P(t,s)} = \sum_{m=1}^{LBs_nict} EBS_nict^P_{(m)(t,s)}$$

$$T_{EBS_nict^O(t,s)} = \sum_{m=1}^{LBs_nict} EBS_nict^O_{(m)(t,s)}$$

$$T_{EBS_nict^D(t,s)} = \sum_{m=1}^{LBs_nict} EBS_nict^D_{(m)(t,s)}$$

Assumptions:

1. When ICT solutions are used, to among other features, reduce carbon emissions in Industrial sectors, it is assumed that in the Use/Operation LC phase the carbon emissions are measured under a certain Load and for a certain type of service;
2. Load = data processed by the network during a unit of time, e.g., 1 week, 1 month, 1 year;
 - "I" index is defined as the "percentage of (average bandwidth ICT infrastructure / total bandwidth that ICT infrastructure can handle)". If "I=1", it means that the applied Load equals the total bandwidth that ICT infrastructure can handle;
3. TS = Type of Service (follow the 5G type of services, e.g., URLLC)
4. LC = Life Cycle, composed by Life Cycle phases Materials, Production, Use/Operation, Disposal;
5. Unit: kgCo2e.

Where:

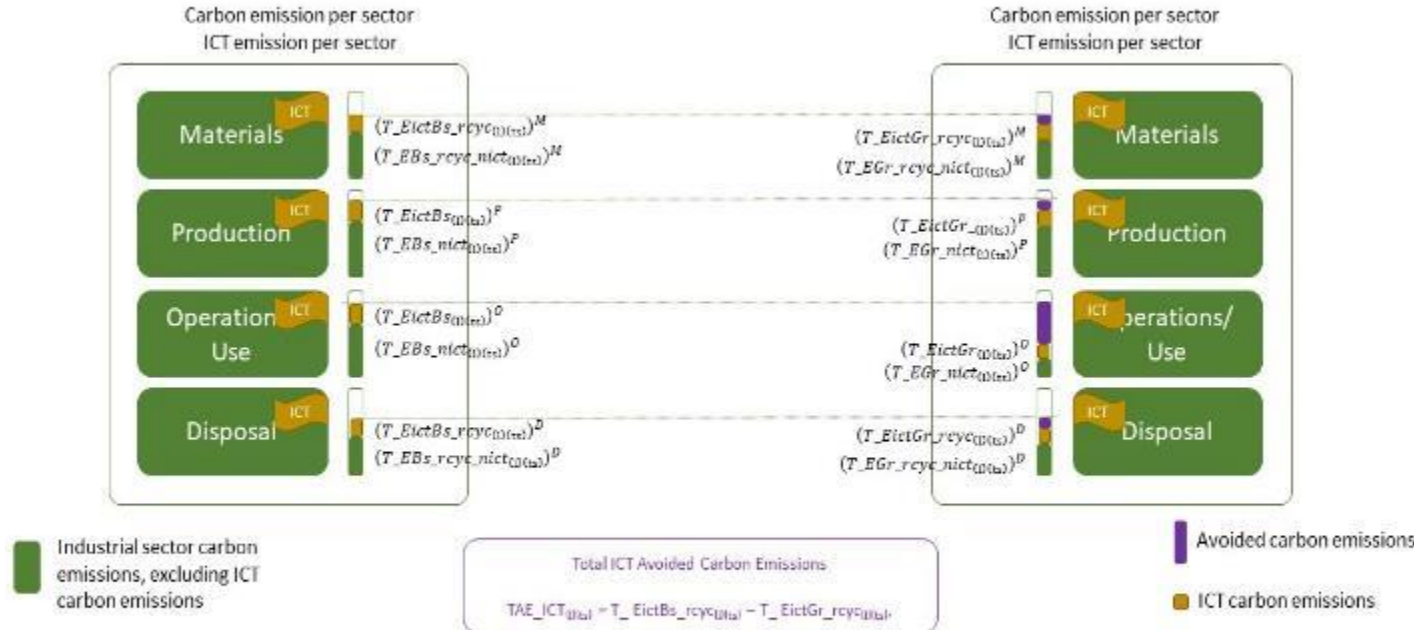
1. $TAE_{(t,s)}$ Total Avoided Carbon Emission Scenario for: (1) the complete LC, excluding the Reuse and Recycle phases, (2) for a certain Load ("I" index) and (3) for a type of service, e.g. follow the classification specified by ITU-T for 5G type of services; Note that the "I" index is defined as the "percentage of (average bandwidth ICT infrastructure / total bandwidth that ICT infrastructure can handle)". If "I=1", it means that the applied Load equals the total bandwidth that ICT infrastructure can handle;
2. $T_{EBS_nict(t,s)}$ Total Carbon Emission Scenario, for Baseline scenario (Bs), but excluding the carbon emission of the applied ICT infrastructure, i.e., carbon emissions of ictBs, for: (1) the complete LC phases, excluding the Reuse and Recycle phases, (2) for a certain Load ("I" index) and (3) for a type of service, e.g. follow the classification specified by ITU-T for 5G type of services;
3. $T_{EictBs(t,s)}$ Total ICT Carbon Emission for Baseline Scenario, i.e., ictBs, for: (1) the complete LC, excluding the Reuse and Recycle phases, (2) for a certain Load ("I" index) and (3) for a type of service, e.g. follow the classification specified by ITU-T for 5G type of services;
4. $T_{EGr_nict(t,s)}$ Total Carbon Emission Scenario, for Green enabled scenario, but excluding the carbon emission of the applied ICT infrastructure, i.e., carbon emissions of ictGr, for: (1) the complete LC, excluding the Reuse and Recycle phases, (2) for a certain Load ("I" index) and (3) for a type of service, e.g. follow the classification specified by ITU-T for 5G type of services;
5. $T_{EictGr(t,s)}$ Total Carbon Emission for Green enabled Scenario, i.e., ictGr, for: (1) the complete LC, excluding the Reuse and Recycle phases, (2) for a certain Load ("I" index) and (3) for a type of service, e.g. follow the classification specified by ITU-T for 5G type of services;
6. T_{EictRB} Total Carbon Emissions from studied product system for the ictGr applied solution due to higher order effects including rebound effects.



AIOTI input on total avoided carbon emissions in vertical sectors, when applying ICT for recycled (with closed loop recycling) products

Carbon footprint (Baseline scenario, with recycling combination 3)

Carbon footprint (Green enabled scenario, with recycling combination 3)



$$\text{Total Avoided Carbon Emissions in Industrial Sector}$$

$$TAE_{(t)} = (T_{EBs_rcyc_nict}_{(t)} + T_{EictBs_rcyc}_{(t)}) - (T_{EGr_rcyc_nict}_{(t)} + T_{EictGr_rcyc}_{(t)}) - T_{Eictrb}$$

$$T_{EBs_rcyc_nict}_{(t)} = \sum_{m=1}^{LBs_nict} EBs_nict_{(m)(t)}^M - \sum_{m=1}^{LBs_nict} (R_{Bs_nict_m} * EBs_nict_{(m)(t)}^M) +$$

$$+ \sum_{m=1}^{LBs_nict} (R_{Bs_nict_m} * E_{cpr_Bs_nict_m}) + T_{EBs_nict}_{(t)}^P + T_{EBs_nict}_{(t)}^O +$$

$$\sum_{m=1}^{LBs_nict} EBs_nict_{(m)(t)}^D - \sum_{m=1}^{LBs_nict} (R_{Bs_nict_m} * EBs_nict_{(m)(t)}^D)$$

Assumptions:

- When ICT solutions are used, to among other features, reduce carbon emissions in Industrial sectors, it is assumed that in the Use/Operation LC phase the carbon emissions are measured under a certain Load and for a certain type of service;
- Load = data processed by the network during a unit of time, e.g., 1 week, 1 month, 1 year;
 - "I" index is defined as the "percentage of (average bandwidth ICT infrastructure / total bandwidth that ICT infrastructure can handle)". If "I=1", it means that the applied Load equals the total bandwidth that ICT infrastructure can handle;
- TS = Type of Service (follow the 5G type of services, e.g., URLLC)
- LC = Life Cycle, composed by Life Cycle phases Materials, Production, Use/Operation, Disposal;
- Unit: kgCo2e.

Where:

- $TAE_{(t)}$ Total Avoided Carbon Emission Scenario for: (1) the complete LC, excluding the Reuse phase, (2) for a certain Load ("I" index) and (3) for a type of service, e.g. follow the classification specified by ITU-T for 5G type of services;
- $T_{EBs_rcyc_nict}_{(t)}$ Total Carbon Emission Scenario, for recycled Baseline scenario (Bs_rcyc), but excluding the carbon emission of the applied ICT infrastructure, i.e., carbon emissions of $ictBs$, for: (1) the complete LC phases, excluding the Reuse phase, (2) for a certain Load and (3) for a type of service, e.g. follow the classification specified by ITU-T for 5G type of services;
- $T_{EictBs_rcyc}_{(t)}$ Total recycled ICT Carbon Emission for Baseline Scenario, i.e., $ictBs$, for: (1) the complete LC, excluding the Reuse phase, (2) for a certain Load and (3) for a type of service, e.g. follow the classification specified by ITU-T for 5G type of services;
- $T_{EGr_rcyc_nict}_{(t)}$ Total Carbon Emission Scenario, for recycled Green enabled scenario (Gr_rcyc), but excluding the carbon emission of the applied ICT infrastructure, i.e., carbon emissions of $ictGr$, for: (1) the complete LC, excluding the Reuse phase, (2) for a certain Load and (3) for a type of service, e.g. follow the classification specified by ITU-T for 5G type of services;
- $T_{EictGr_rcyc}_{(t)}$ Total recycled ICT Carbon Emission for Green enabled Scenario, i.e., $ictGr$, for: (1) the complete LC, excluding the Reuse and Recycle phases, (2) for a certain Load and (3) for a type of service, e.g. follow the classification specified by ITU-T for 5G type of services;
- $T_{Eicttrb}$ Total Carbon Emissions from studied product system for the $ictGr$ applied solution due to higher order effects including rebound effects;
- $E_{cpr_Gr_nict_k}$ represents GHG emissions of the circularity process of each product component (k) of the recycled Green enabled scenario assuming that: (1) $R_{Gr_net} = 1$ (complete product is recycled) and (2) excluding the carbon emission of the applied ICT infrastructure, i.e., carbon emissions of $ictGr$;
- $R_{Bs_nict_m}$: represents the recycling rate of the material of each product/component (m) used for the recycled Baseline scenario, excluding the materials used for the ICT infrastructure.