Circular Footprint Formula

Webinar; Environmental Footprint (EF) transition phase

08 October 2019

Marc-Andree Wolf
maki Consulting GmbH

Ulbert Hofstra
SGS Intron B.V.

Gert-Jan Vroege
SGS Search B.V.

An De Schryver
Production Coordinator,
European Commission, DG ENV

Luca Zampori
European Commission, JRC

Quality assurance: Kirana Wolf
maki Consulting GmbH

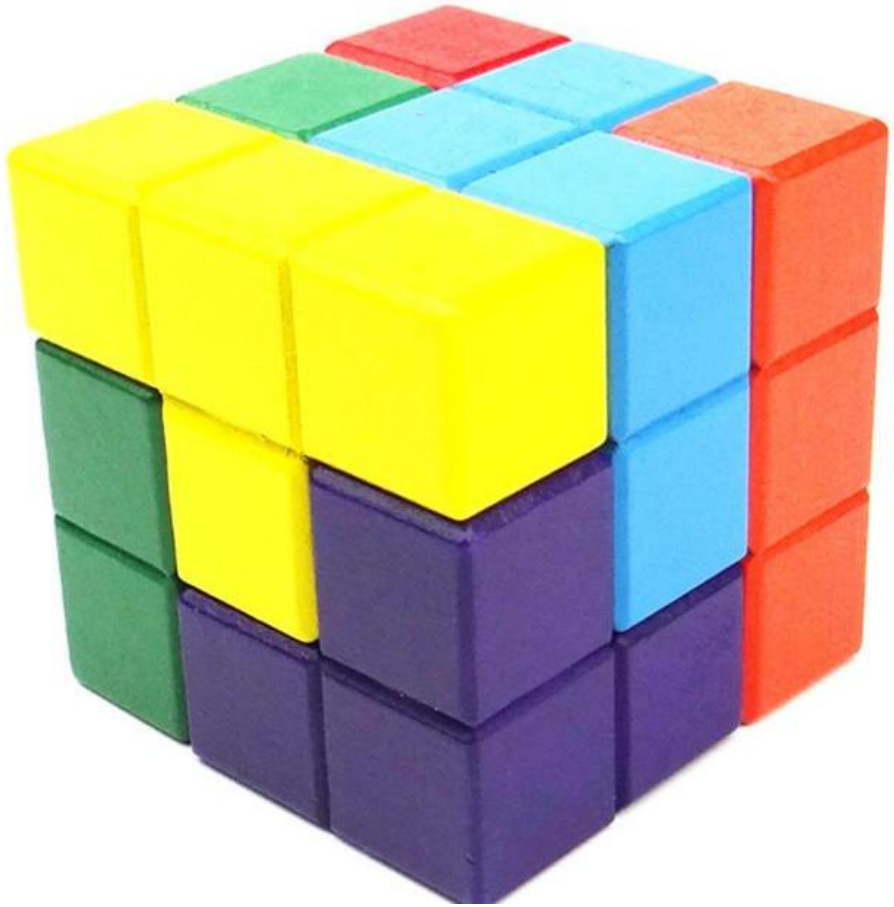
Agenda

- The Circular Footprint Formula (CFF)
  - Why the CFF
  - Overview
  - The components of the CFF
  - Determining the values of the CFF variables and parameters
- Applying the CFF – example of PET blister packaging
- Special cases: intermediate products, other specific aspects
- Questions & answers

Why the Circular Footprint Formula?

Recycling and energy recovery, as well as using secondary materials and energy leads to questions in EF work on how to account for benefits and burdens of these processes. For reproducibility and fairness, guidance is needed:

- Where is the boundary between the first and the second product system?
- How should benefits and burdens of generating and of using recycled material be shared between the first and the second product system?
- As generated secondary materials and energy carriers avoid primary materials and energy carriers being produced: how to select the specific primary material and/or energy that is avoided?
- How to handle downcycling, i.e. differences in quality between secondary material or energy and the primary material or energy?
- How to avoid double counting or gaps of benefits and burdens?



Overview

Circular Footprint Formula (CFF)

Life Cycle Inventory (LCI) of primary material

LCI associated to secondary material input

LCI of the material recycling (or part/product reuse) process minus the credit for avoided primary material

Material

$$= (1 - R_1)E_V + R_1 \times \left(AE_{recycled} + (1 - A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1 - A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

Energy

$$+ (1 - B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

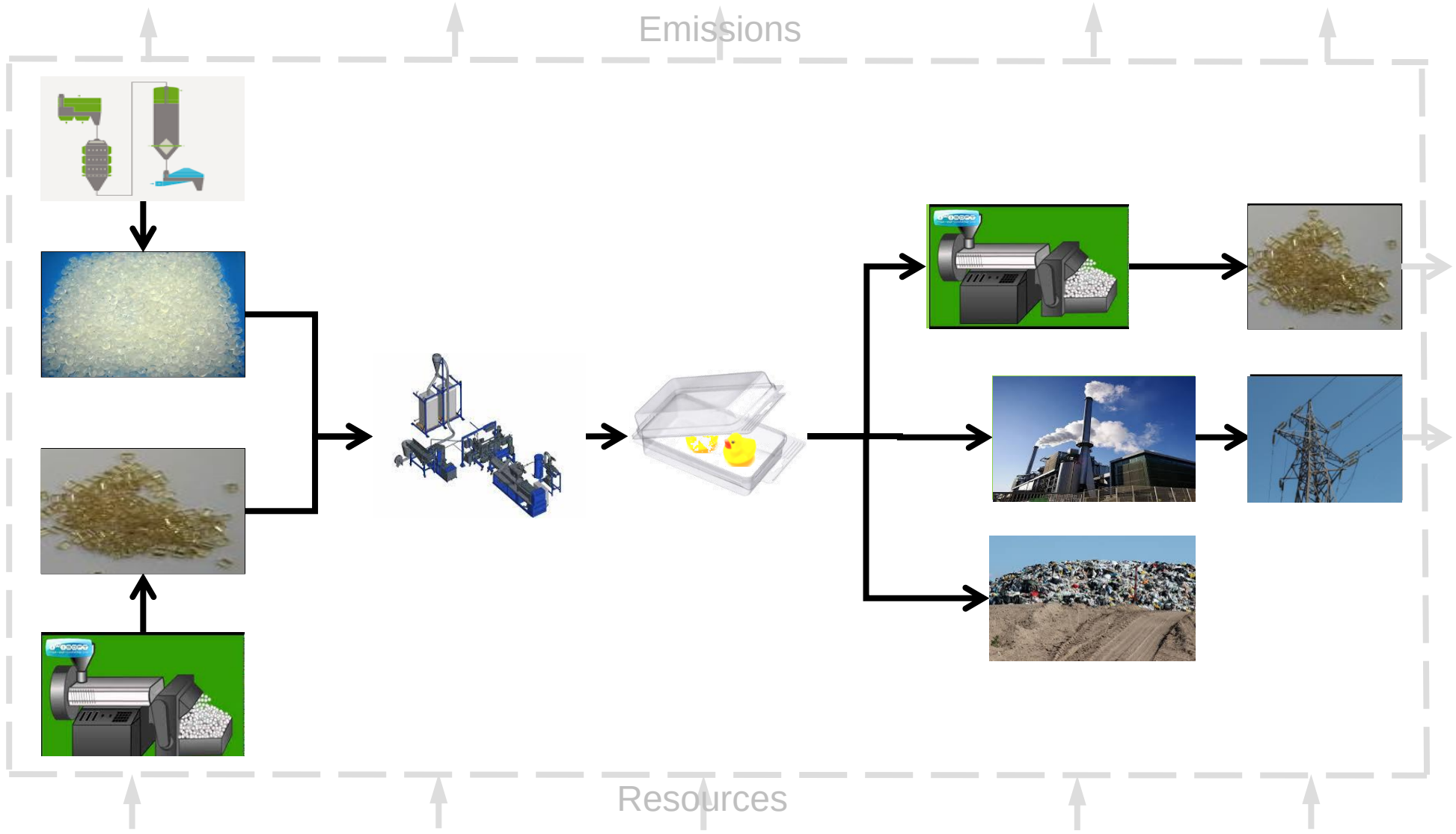
Disposal

$$+ (1 - R_2 - R_3) \times E_D$$

LCI of the disposal of remaining waste

LCI of the energy recovery process minus the credit for avoided primary energy

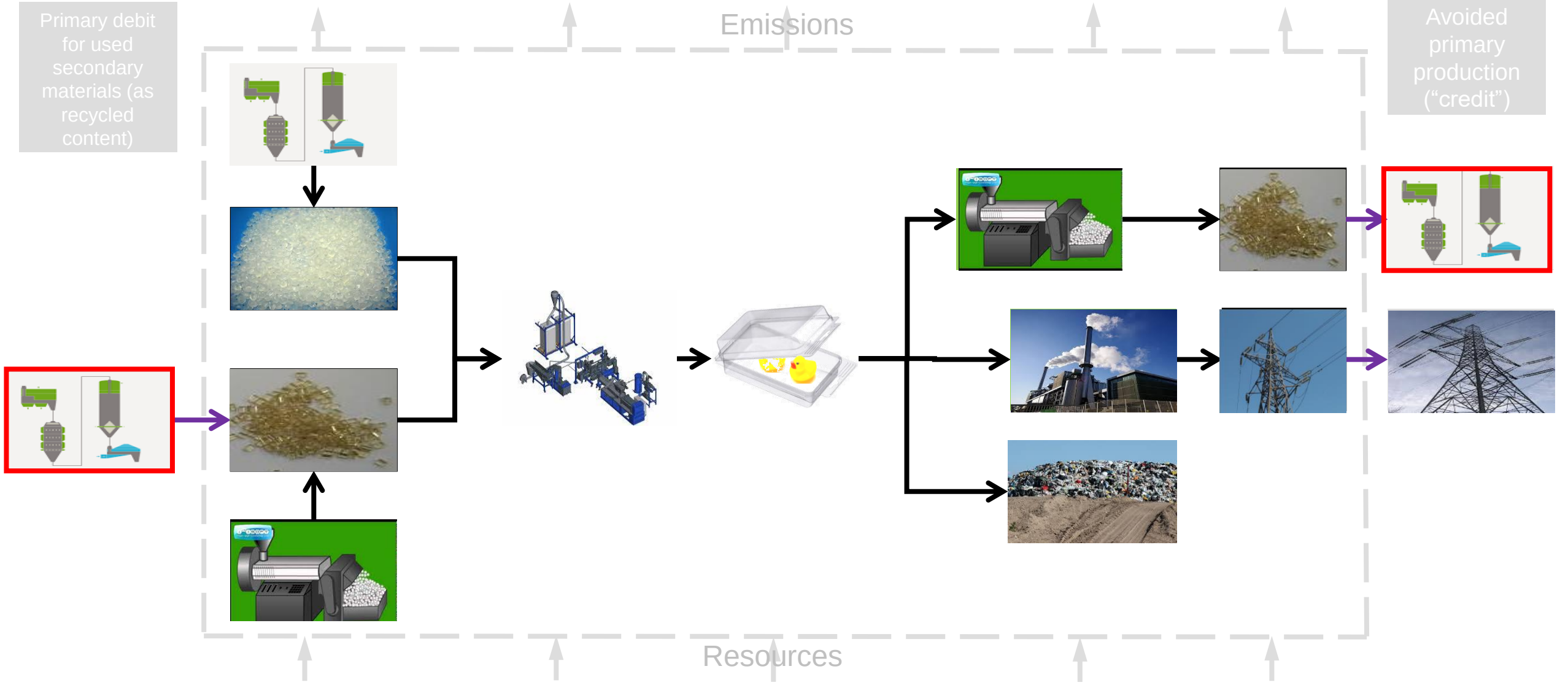
From secondary materials and energy input and output ...



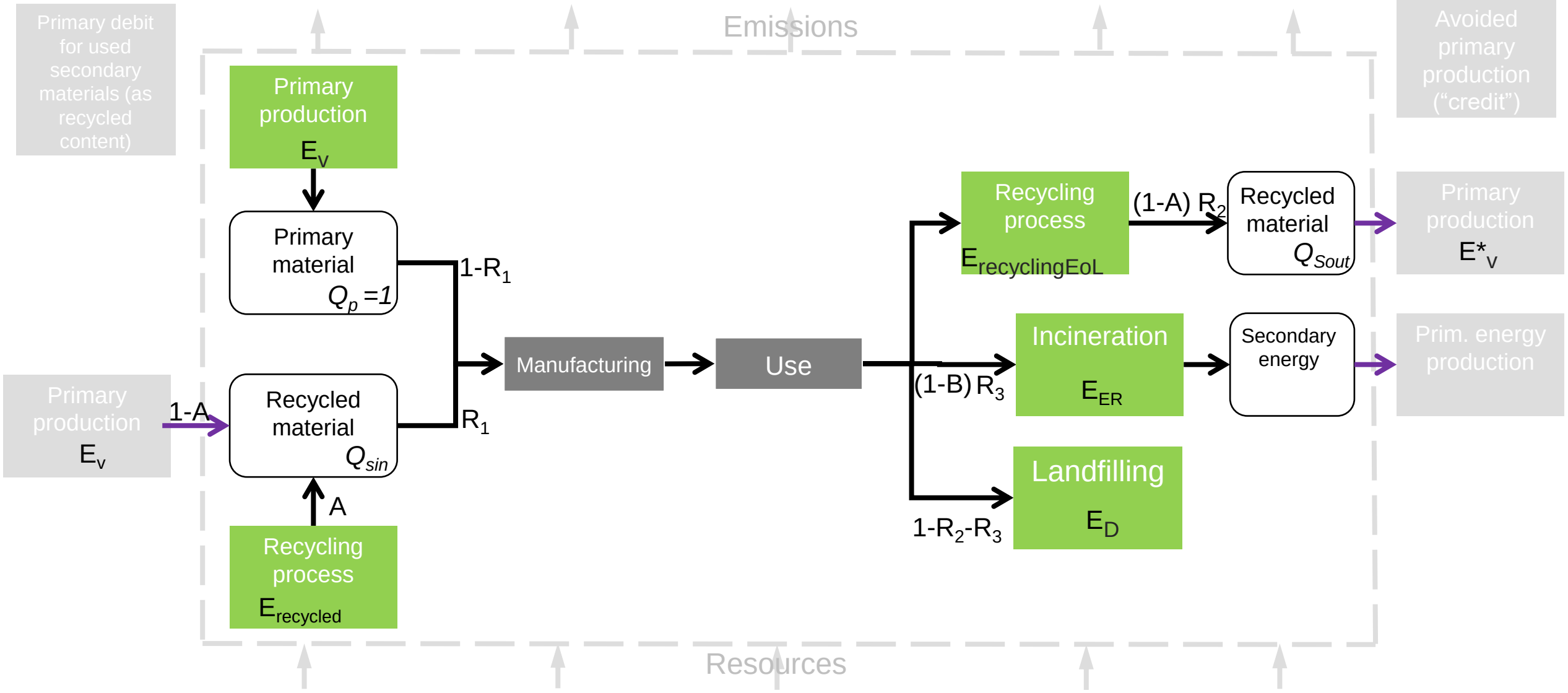
Notes: Energy and consumables input, transport, storage and other activities are always included in the model, but graphic focuses on core steps. Waste/ashes/slag… from recycling and incineration are to be modelled to go to landfill (not shown).

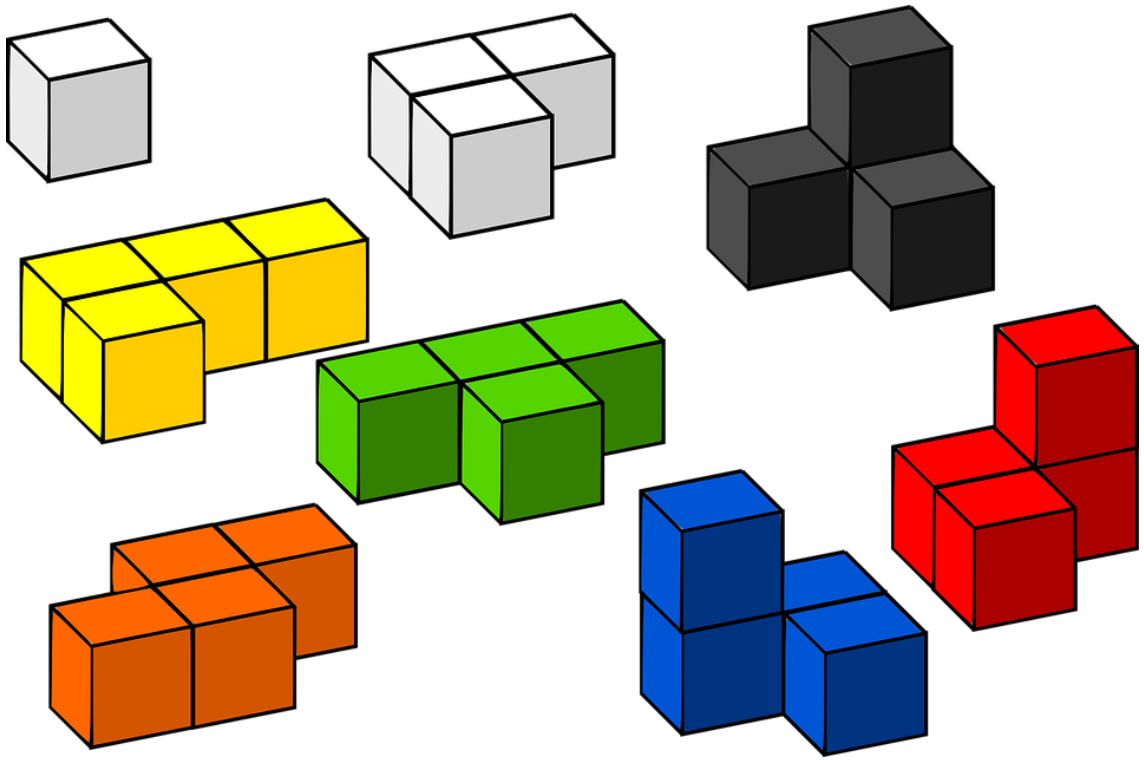
... to connection with subsequent and preceding life cycles via crediting and debiting ...

thinkstep a sphera company | maki Consulting GmbH Life cycle expert services | SGS



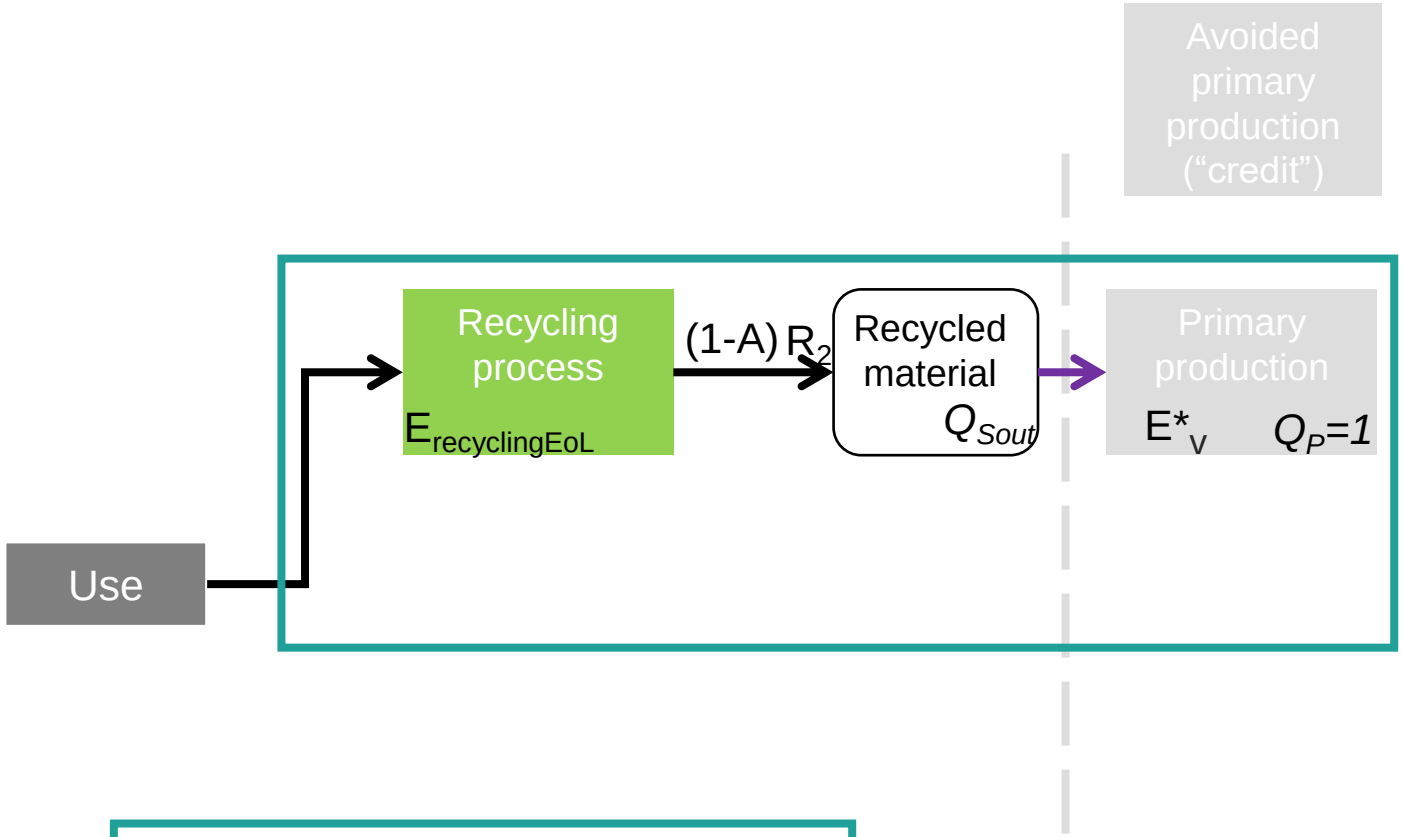
... to abstraction and formularisation.





The components of the CFF

End-of-life: recycling and avoided primary production



Material

$$(1-R_1)E_V + R_1 \times \left(AE_{recycled} + (1-A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1-A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

Energy

$$(1-B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

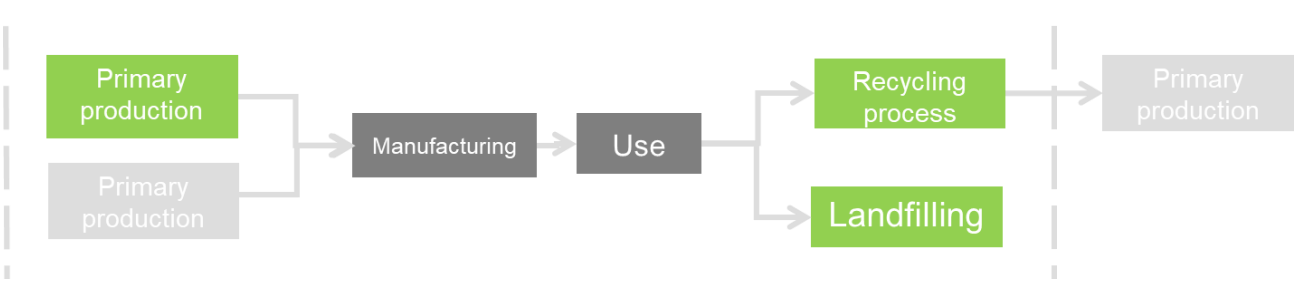
Disposal

$$(1-R_2-R_3) \times E_D$$

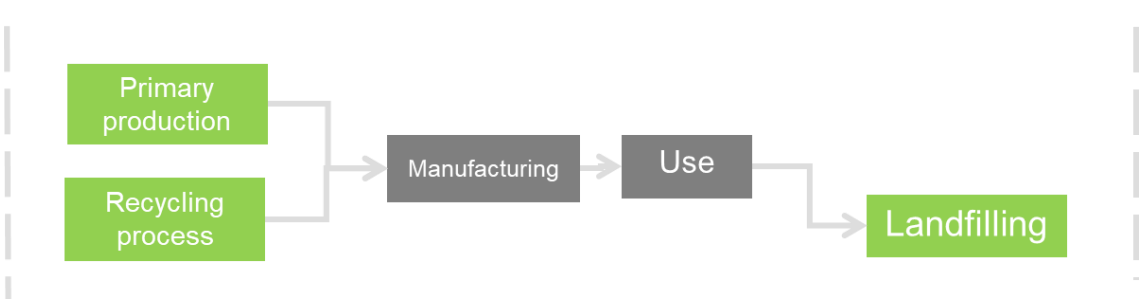
Life Cycle Inventory (LCI) of the material recycling (or part/product reuse) process minus the credit for avoided primary material

CFF: Factor “A”

» The factor A allocates burdens and benefits from recycling and primary material production between the two connected life cycles



A=0 (“0:100 approach”)



A=1 (“100:0 approach”)

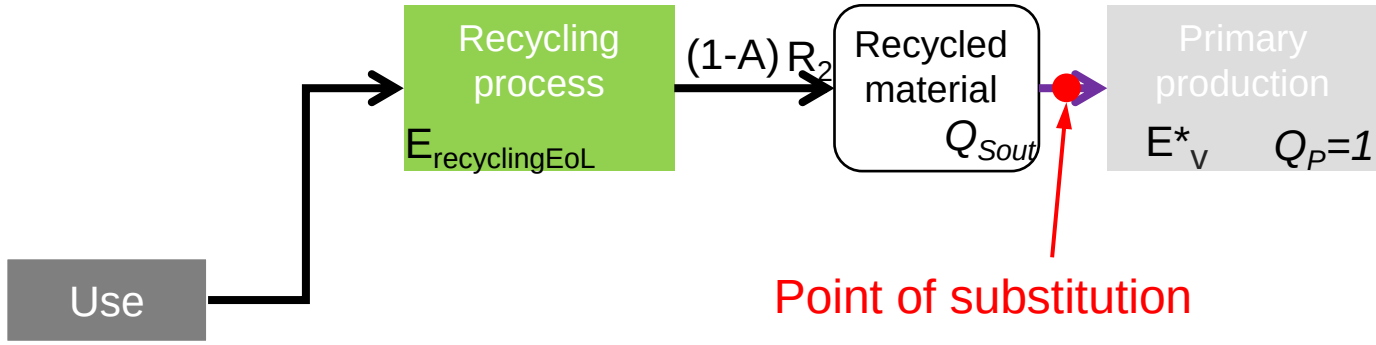
$$(1-A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

In CFF: A = 0.2, 0.5, or 0.8 . “A” is representing the market situation:

- **A = 0.2**: more high quality secondary material demanded than produced (e.g. many metals, glass, …); indicator: market price is close to / same as primary
- **A = 0.8**: the opposite is the case (e.g. textiles, …); indicator: market price is very low compared to primary
- **A = 0.5**: market situation is more balanced or unknown

Point of substitution

https://www.pexels.com/photo/factory-glass-machinery-melting-131820/



- Necessary to be determined for the material part of the formula, i.e. what exactly is E_v and E^*_v (and to which point the recycling at EoL is to be modelled)
- Point of substitution = point in the value chain where the secondary material substitutes primary material(s)
- Not always straightforward, e.g.:
  - glass cullet vs. melted glass
  - steel scrap vs. secondary steel slab
  - downcycled mixed polymers vs. fence/park bench (“open loop”)

CFF: Quality ratios Q_{Sin}/Q_P and Q_{Sout}/Q_P

$$(1-A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

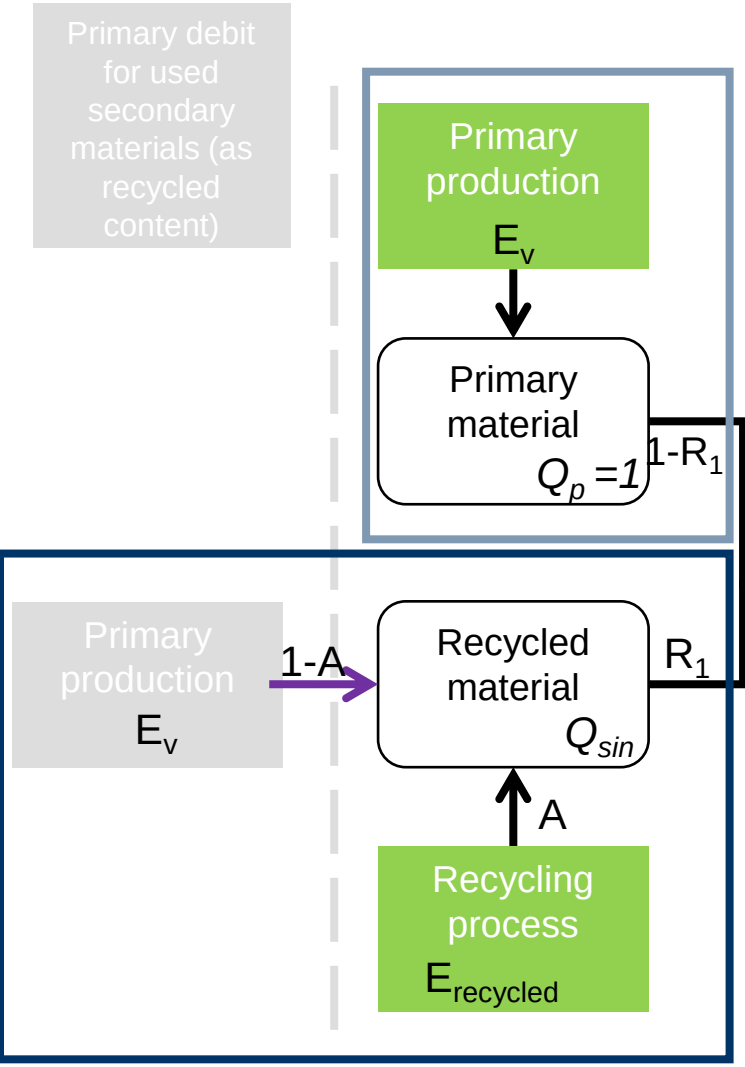
- Quality ratios Q_{Sin}/Q_P and Q_{Sout}/Q_P shall be determined at the point of substitution per application or material and be based on:

  1. Economic aspects: i.e. price ratio of secondary compared to primary materials at the point of substitution. In case the price of secondary materials is higher than that of the primary ones, the quality ratios shall be set equal to 1.

  2. When economic aspects are less relevant than physical aspects, the latter may be used.

- Accounts for quality of both ingoing and outgoing recycled materials
  - If $\mathbf{E_v = E^*_v}$, the two quality ratios are needed: $Q_{Sin}/_{QP}$ associated to the recycled content, and Q_{Sout}/Q_P associated to recycling at EoL -> to capture downcycling
  - If $\mathbf{E_v \neq E^*_v}$, recycling to a different product (“open-loop recycling”), one quality ratio is needed: $Q_{Sin}/_{QP}$ associated to the recycled content. $Q_{Sout}/_{QP}$ is integrated in E^*_v (via defining the equivalent functional unit) .

Recycled content – the credit-debit balance among connected life cycles



LCI of primary material

LCI associated to secondary material input

Material

$$(1 - R_1)E_V + R_1 \times \left(AE_{recycled} + (1 - A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1 - A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

Energy

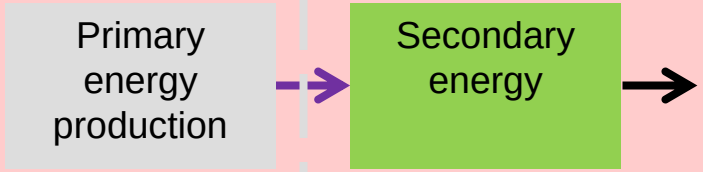
$$(1 - B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

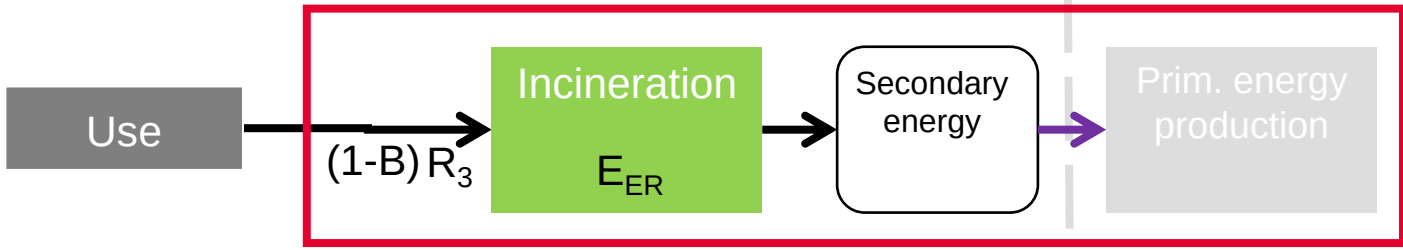
Disposal

$$(1 - R_2 - R_3) \times E_D$$

End-of-life: waste-to-energy and avoided primary production (plus analogous debit for secondary energy use)

! "*To avoid double-counting between the current and the subsequent system in case of energy recovery, the subsequent system shall model its own energy use as primary energy*."





Material

$$(1-R_1)E_V + R_1 \times \left(AE_{recycled} + (1-A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1-A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

Energy

$$(1-B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

Disposal

$$(1-R_2-R_3) \times E_D$$

LCI of the energy recovery process burdens minus the credit for avoided primary energy

CFF: Factor “B”

- The factor B is used as an allocation factor between connected life cycles for EoL energy recovery processes and generated secondary energy
- B is equal to 0 as default, i.e. 100% of generated, externally used energy is credited at the producer and debited at user of the secondary energy (i.e. both waste-to-energy burdens and avoided primary production benefits)
- This also applies to waste fuels (e.g. of used rubber in cement kilns)

End-of-life: landfilling (includes other EoL treatment without product output)

Material

$$(1 - R_1)E_V + R_1 \times \left(AE_{recycled} + (1 - A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1 - A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

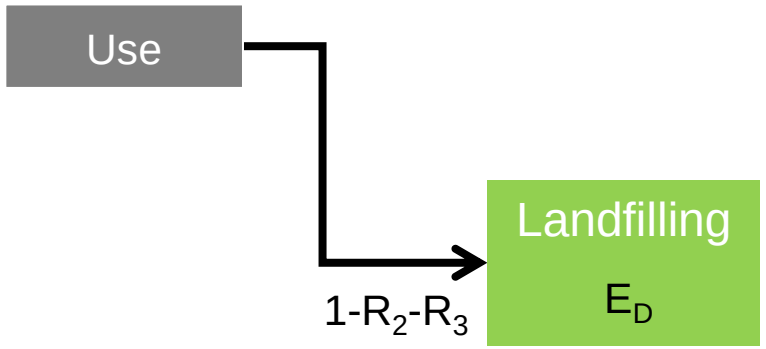
Energy

$$(1 - B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

Disposal

$$(1 - R_2 - R_3) \times E_D$$

LCI of the disposal of remaining waste



Circular Footprint Formula (CFF)

Life Cycle Inventory (LCI) of primary material

LCI associated to secondary material input

LCI of the material recycling (or part/product reuse) process minus the credit for avoided primary material

Material

$$= (1 - R_1)E_V + R_1 \times \left(AE_{recycled} + (1 - A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1 - A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

Energy

$$+ (1 - B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

Disposal

$$+ (1 - R_2 - R_3) \times E_D$$

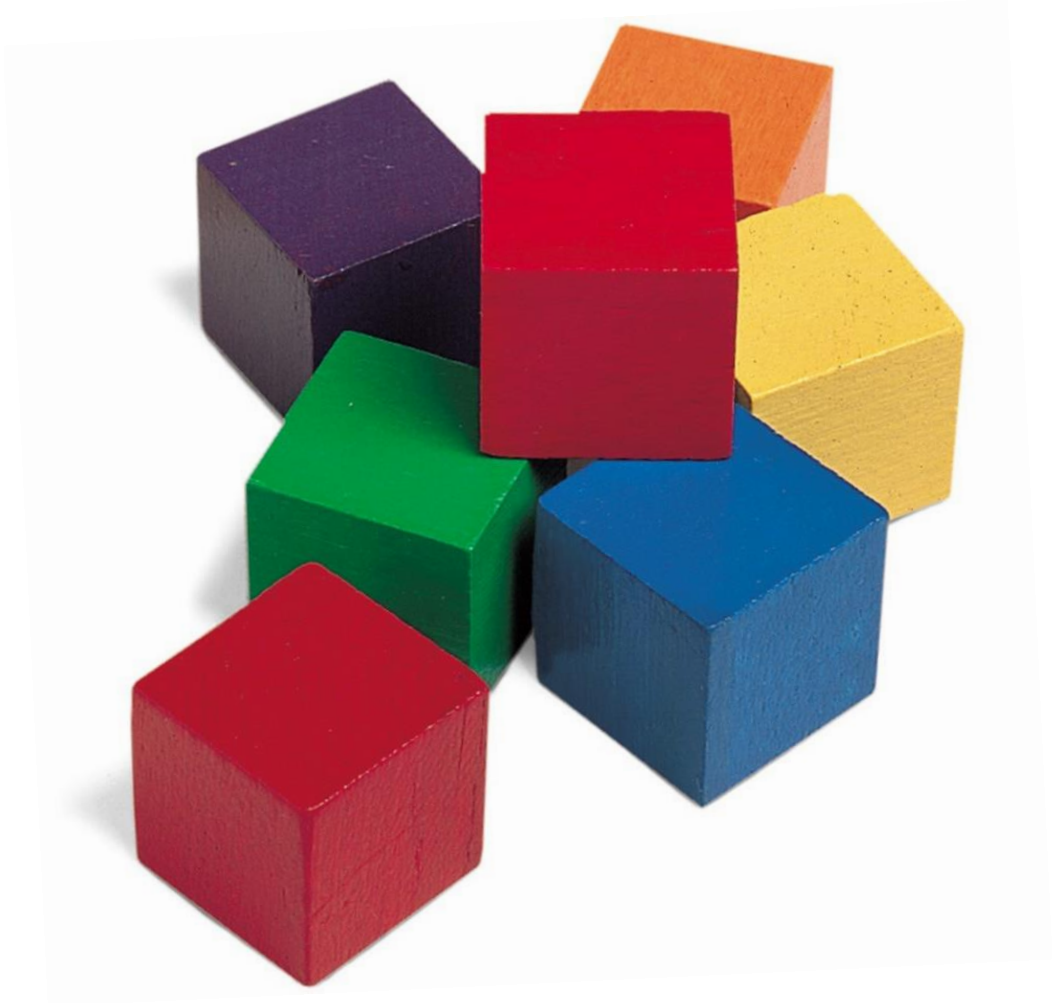
! Also used secondary energy to be modelled as replaced primary energy (mix)!

LCI of the disposal of remaining waste

LCI of the energy recovery process minus the credit for avoided primary energy

List of variables and parameters of the CFF

A	Allocation factor of burdens and benefits (jointly: “credits”) between supplier and user of recycled materials.
B	Allocation factor of energy recovery processes. It applies both to burdens and benefits.
$\mathbf{Q_{Sin}}$	Quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution.
$\mathbf{Q_{Sout}}$	Quality of the outgoing secondary material, i.e. the quality of the recycled material at the point of substitution.
$\mathbf{Q_P}$	Quality of the primary material, i.e. quality of the virgin material.
$\mathbf{R_1}$	Proportion of material in the input to the production that has been recycled from a previous system.
$\mathbf{R_2}$	Proportion of the material in the product that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant.
$\mathbf{R_3}$	Proportion of the material in the product that is used for energy recovery at EoL.
$\mathbf{E_{recycled}}$	Specific emissions and resources consumed (per functional unit) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process.
$\mathbf{E_{recyclingEoL}}$	Specific emissions and resources consumed (per functional unit) arising from the recycling process at EoL, including collection, sorting and transportation process.
$\mathbf{E_v}$	Specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material.
$\mathbf{E^*_v}$	Specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials.
$\mathbf{E_{ER}}$	Specific emissions and resources consumed (per functional unit) arising from the energy recovery process (e.g. incineration with energy recovery, landfill with energy recovery, etc.).
$\mathbf{E_{SE,heat}}$ **and** $\mathbf{E_{SE,elec}}$	Specific emissions and resources consumed (per functional unit) that would have arisen from the specific substituted energy source, heat and electricity respectively.
$\mathbf{E_D}$	Specific emissions and resources consumed (per functional unit) arising from disposal of waste material at the EoL of the analysed product, without energy recovery or other usable product output.
$\mathbf{X_{ER,heat}}$ **and** $\mathbf{X_{ER,elec}}$	The efficiency of the energy recovery process for both heat and electricity.
LHV	Lower heating value of the material in the product that is used for energy recovery.



Determining the values of the CFF variables and parameters

CFF: Recycled content „R_1“

Situation	Option	Most relevant process	Other process
Situation 1: Process run by the company using the PEFCR	Option 1	Specific R_1 value	
	Option 2	Specific R_1 value	Default (application-specific) R_1 value
Situation 2: Process not run by the company but with access to (company)-specific information	Option 1	Supply-chain specific R1 value	
	Option 2	Default (application-specific) R_1 value	
Situation 3: Process not run by the company and without access to specific information	Option 1	Default (application-specific) R_1 value	

- Default values are given in Annex C of the PEF method document
- For PEF studies on product groups and organisations for which a PEFCR is not available, and for common requirements on traceability and evidence needed, please see PEF method document p. 69 f

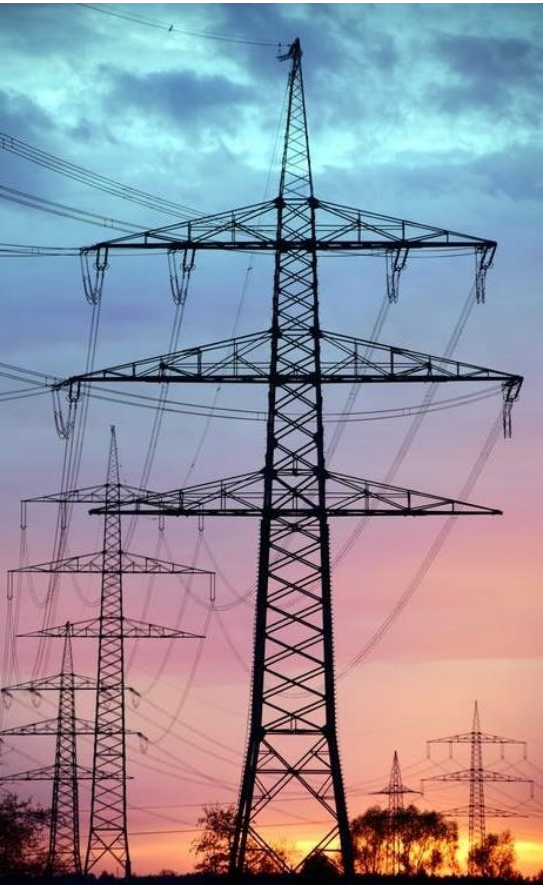
CFF: Recycling output rate „R_2“

- The **PEFCR** shall list the default R_2 values (i.e. as provided in Annex C of the PEF method) to be used when no company-specific values are available
- In case no company-specific R_2 values are available, the Technical Secretariat of PEFCR selects and fixes either:
  - R_2 shall be equal to 0
  - TS generates new statistics to assign a new R_2 value for use in PEF studies; to be approved by the Commission

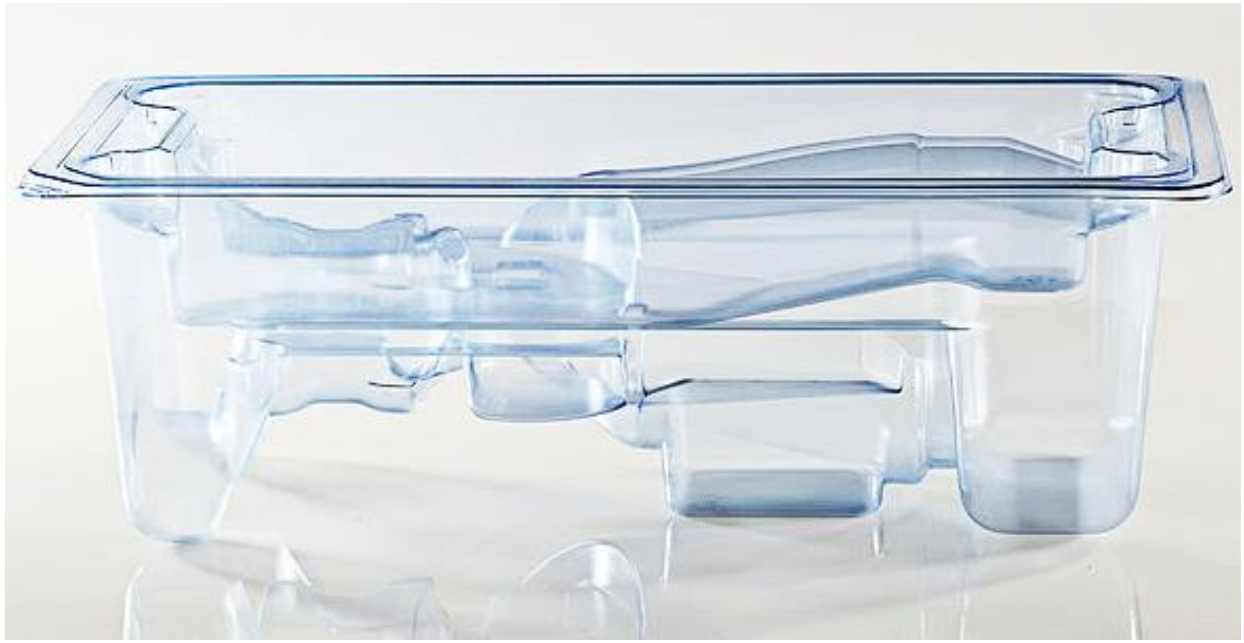
For **PEF studies**:

- Evaluate the recyclability of the material, provide evidence (see p. 72 of PEF method), use company-specific values if available
- If no company-specific values are available and the criteria for the evaluation of recyclability are fulfilled, application-specific R_2 values from Annex C shall be used
  - If an R_2 value is not available for a specific country, then the European average shall be used;
  - If an R_2 value is not available for a specific application, the R_2 values of the material shall be used (e.g. materials' average);
  - In case no R_2 values are available, R_2 shall be set equal to 0 or new statistics may be generated in order to assign an R_2 value in the specific situation.

Default values for CFF parameters → Annex C



- Factor A (for sharing recycling burdens and benefits among connected life cycles); either “0.2”, “0.5” or “0.8”
- Factor B (for sharing energy recovery burdens and benefits among connected life cycles); always “0”
- Q_{Sin}, $Q_{Sout,}$ - downcycling factors for secondary materials
- Recycled content R_1
- Recycling rate R_2
- Shares of landfilling and of waste incineration per country and for EU28



Example PET blister packaging as part of a PEF study on a packaged product

Example PET blister packaging, 20 g

Material

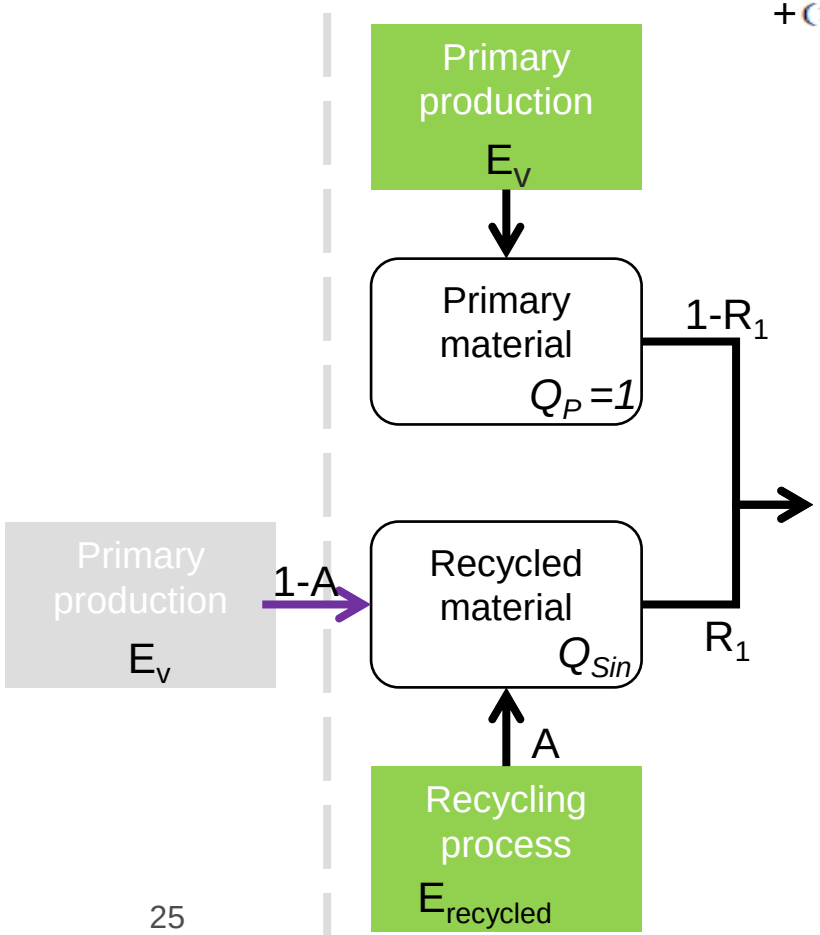
$$= \boxed{(1-R_1)E_V} + \boxed{R_1 \times \left(AE_{recycled} + (1-A)E_V \times \frac{Q_{Sin}}{Q_p}\right)} + (1-A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

Energy

$$+(1-B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

Disposal

$$+(1-R_2-R_3) \times E_D$$



All values are for illustration only!

E_v	0.0442 kg CO_2-eq (per 20 g PET)
$E_{recycled}$	0.0133 kg CO_2-eq (per 20 g PET)
Q_{Sin}	1 (SSP high qual. recycled PET pellets)
Q_P	1
A	0.5
R_1	0.2 (company specific; default = 0)

$$(1-R_1)E_v + R_1\, x\, (AErecyc_{led} + (1-A)E_v \frac{Q_{Sin}}{Q_P}) = \mathbf{0.0411}\ \text{kg } CO_2\text{-eq}$$

Example PET blister packaging, 20 g

Material

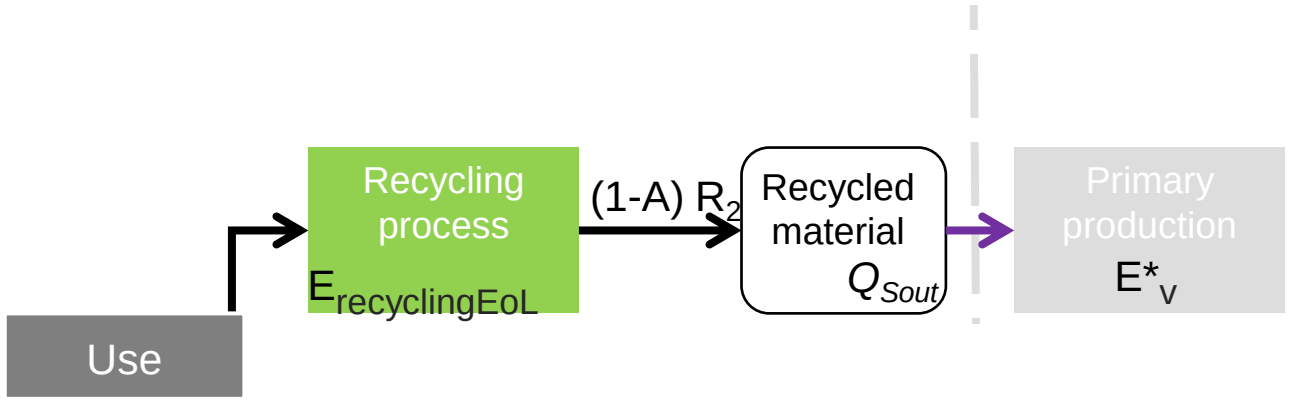
$$= (1-R_1)E_V + R_1 \times \left(AE_{recycled} + (1-A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1-A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

Energy

$$+(1-B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

Disposal

$$+(1-R_2-R_3) \times E_D$$



E^*_V	0.0442 kg CO_2-eq (per 20 g PET)
$E_{recyclingEoL}$	0.0133 kg CO_2-eq (per 20 g PET)
Q_{Sout}	1 (SSP recycled PET pellets)
Q_P	1
A	0.5
R_2	0.4 (company specific, default = 0)

$$(1-A)R_2 \times (E_{recyclingEoL} - E^*_V \frac{Q_{Sout}}{Q_P}) = -0.00618 \text{ kg } CO_2\text{-eq}$$

Example PET blister packaging, 20 g

Material

$$= (1 - R_1)E_V + R_1 \times \left(AE_{recycled} + (1 - A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1 - A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

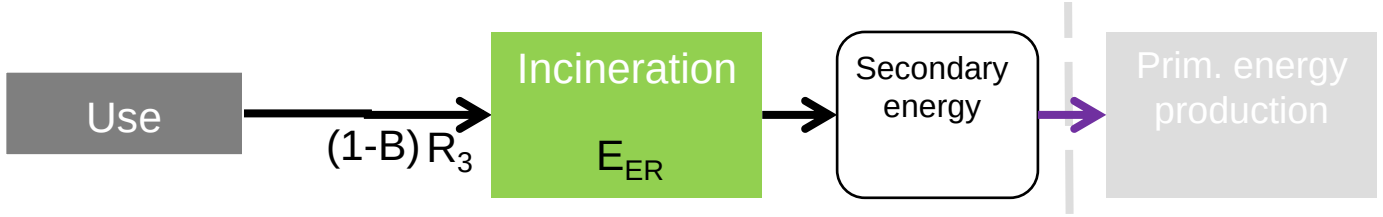
Energy

$$+ (1 - B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

Disposal

$$+ (1 - R_2 - R_3) \times E_D$$

No use of secondary energy in PET blister packaging production step, hence no debit on secondary energy.



E_{ER} 0.0279 kg CO_2-eq (per 20 g PET)
B 0
R_3 0.27

(1-B) R_3 x (E_{ER} - LHV x $X_{ER,heat}$ x $E_{SE,heat}$ – LHV x $X_{ER,elec}$ x $E_{SE,elec}$) = 0.00753 kg CO_2-eq

Example PET blister packaging, 20 g

thinkstep a sphera company | maki Consulting GmbH Life cycle expert services | SGS

Material

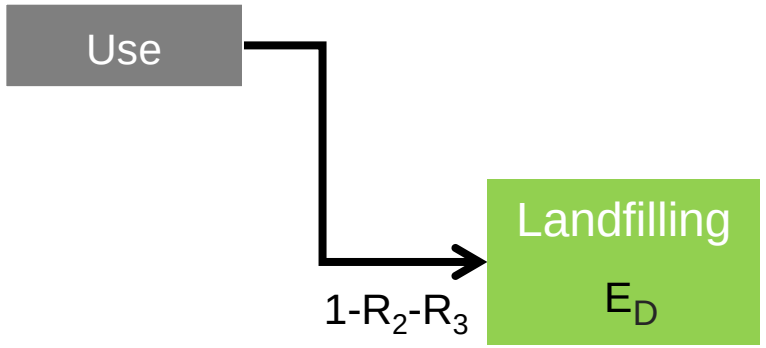
$$= (1 - R_1)E_V + R_1 \times \left(AE_{recycled} + (1 - A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1 - A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

Energy

$$+ (1 - B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

Disposal

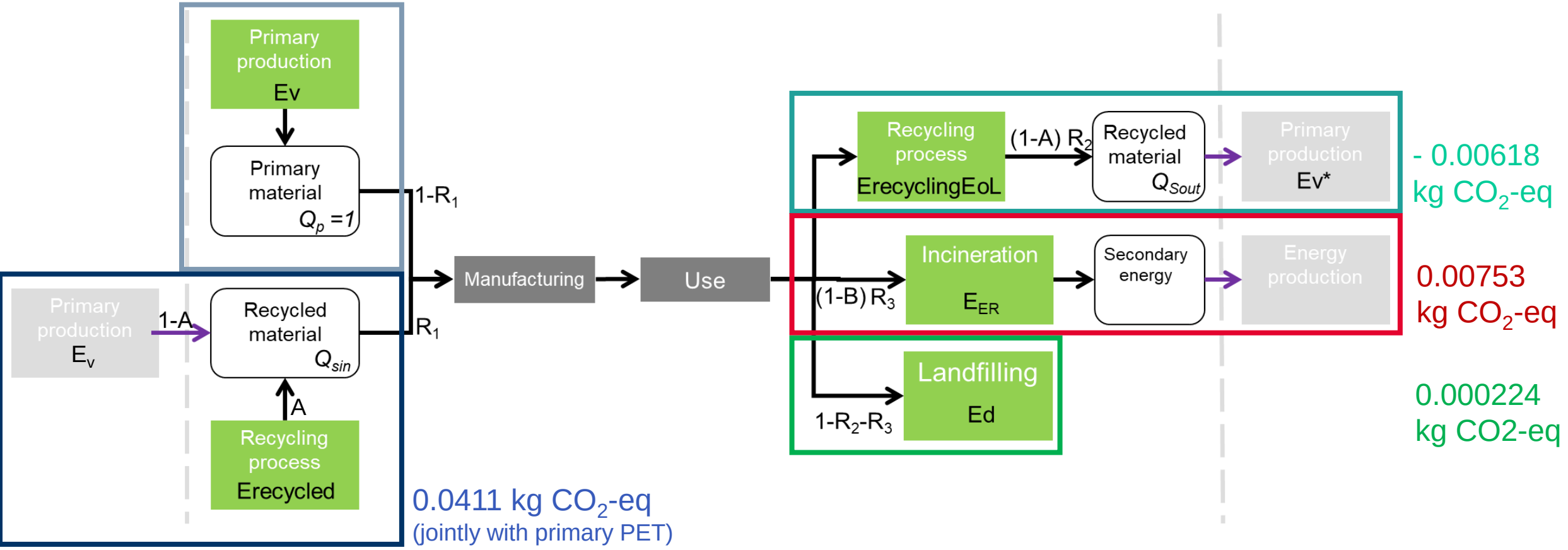
$$+ (1 - R_2 - R_3) \times E_D$$



E_D 0.000680 kg CO_2-eq (per 20 g PET)
R_2 0.4 (company specific, default = 0)
R_3 0.27

$(1 - R_2 - R_3)$ x E_D = 0.000224 kg CO_2-eq

Example PET blister packaging, 20 g



= 0.0411 – 0.00618 + 0.00753 + 0.000224 = **0.0427** kg CO_2-eq per 1 PET blister packaging from CFF calculation

! The PEF study shall report all parameter and variable values used, the source and – if not default – provide evidence.

Special cases

How to apply the CFF to intermediate products

- Intermediate products --> cradle-to-gate PEF studies (e.g. metal sheets, flexible packaging, paper)
- The PEFCR shall prescribe…
  - the use of the CFF,
  - to exclude the end-of-life by setting R_2, R_3 and E_D to 0,
  - application- or material-specific A-values for the product, and
  - to use and report results with two types of A values for the product in scope:
    - Setting A = 1 in the PEF profile calculation
    - Setting A = default value as listed in PEFCR to be used when creating EF compliant datasets

Example: metal sheets, as intermediate product

Material part of CFF (i.e. energy and landfill part still to be added):

$$(1 - R_1)E_v + R_1\, x \left(AE_{recycled} + (1 - A)E_v \frac{Q_{Sin}}{Q_P} \right) + (1 - A)R_2 \text{ x } (E_{recyclingEoL} - E^*_v \frac{Q_{Sout}}{Q_P})$$

Metal sheets (steel) for building (from pilot phase):

A = 1 / 0.2; R_1 = 0.54; R_2 = 0; R_3=0, Q_{Sin}/Q_P = 1; Q_{Sout}/Q_P = 1

Setting A = 1 in the PEF profile calculation:

» **$0.46E_v + 0.54(E_{recycled}) + 0$**

Setting A = default value (“0.2”) as listed in PEFCR to be used for additional technical information and for creating EF-compliant data sets:

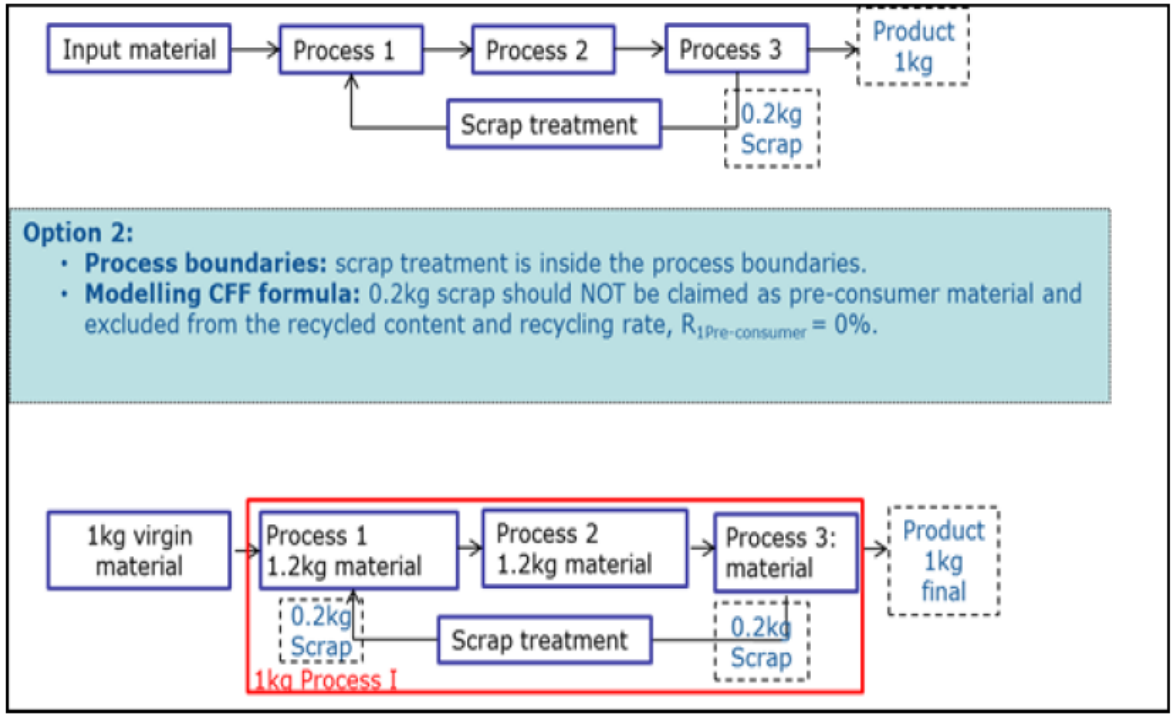
» **$0.46E_v + 0.54(0.2E_{recycled} – 0.8E_v) + 0$**

How to deal with specific aspects

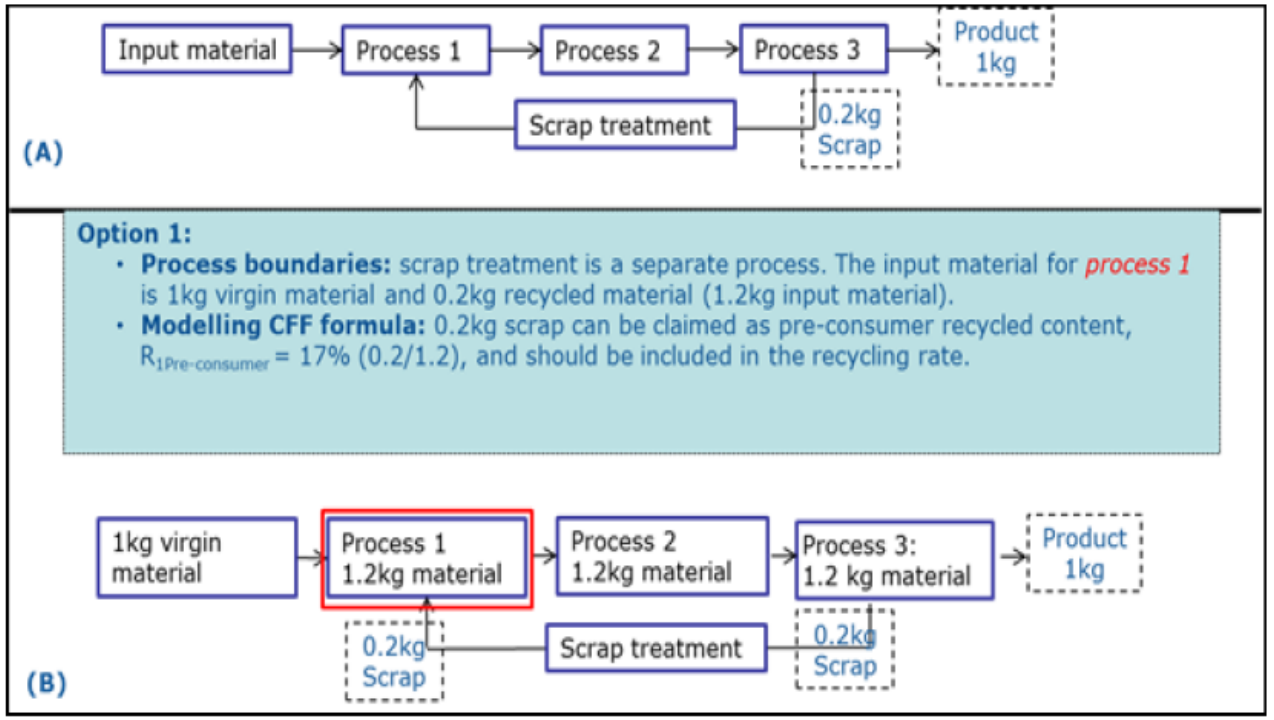
- *Recovery of bottom ashes or slag from incineration*
- *Landfill with energy recovery*
- *Municipal solid waste*
- *Compost and anaerobic digestion/ sewage treatment*
- *Waste materials used as fuel on input side*
- *Modelling complex products*
- *Extended product lifetime*
- *Reuse and refurbishment*
- *Reuse (e.g. of packaging)*

For details, please see PEF method document, p. 74 ff

How to deal with pre-consumer scrap - options



Any material that circulates within a process chain or pool of process chains is excluded from being defined as recycled content and it is not included in R_1 → Scrap is not claimed as pre-consumer recycled content



The impacts to produce the input material that leads to the pre-consumer scrap in question shall be allocated to the product system that generated this scrap → Scrap is claimed as pre-consumer recycled content

Questions & answers

Further questions: EF_Helpdesk@thinkstep.com

Link Collection

- Further reading about the EF transition phase
- EF Wiki
- Training calendar
- PEF method
- OEF method
- Description of governance bodies
- Existing PEFCRs/OEFSRs, e-learning tools, and technical reports
- Rules for EF compliant data sets

- Email address technical helpdesk: EF_Helpdesk@thinkstep.com
- Email address EF Team at DG ENV: env-environmental-footprint@ec.europa.eu

Source: Marc-A. Wolf; freely usable under CC license

Thank you for your interest and time!

The contents of this webinar have been produced under service contract 07.0203/2017/SI2.762537/SER/ENV.B.1 with the European Commission. The slides' content has been approved by the Commission, while opinions expressed during the webinar are those of the contractors only and do not represent the EU's official position.