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Centre interuniversitaire de recherche sur le cycle de vie des produits, procédés et services

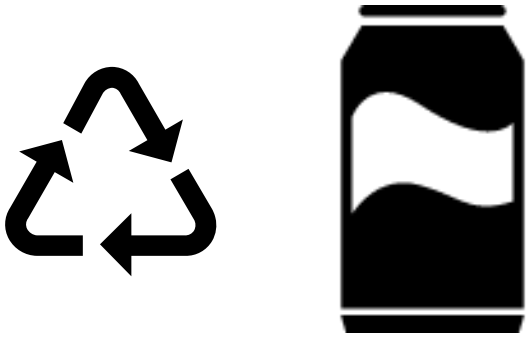
ENV510 – Lab 3 – End of life and recycling
Carbon footprint of a carbonated water can

POLYTECHNIQUE MONTRÉAL

WORLD-CLASS ENGINEERING

Context

- During the first lab, we have calculated and modeled on openLCA the carbon footprint af a carbonated water
- In the second lab, we have adapted the aluminium production process to a more realistic process (Quebec and China) and compared the new results to the old one
- So far, we assumed that the can was simply landfilled
- During this lab, we will calculate and model recyling of the aluminum can according different sceanrios and approaches



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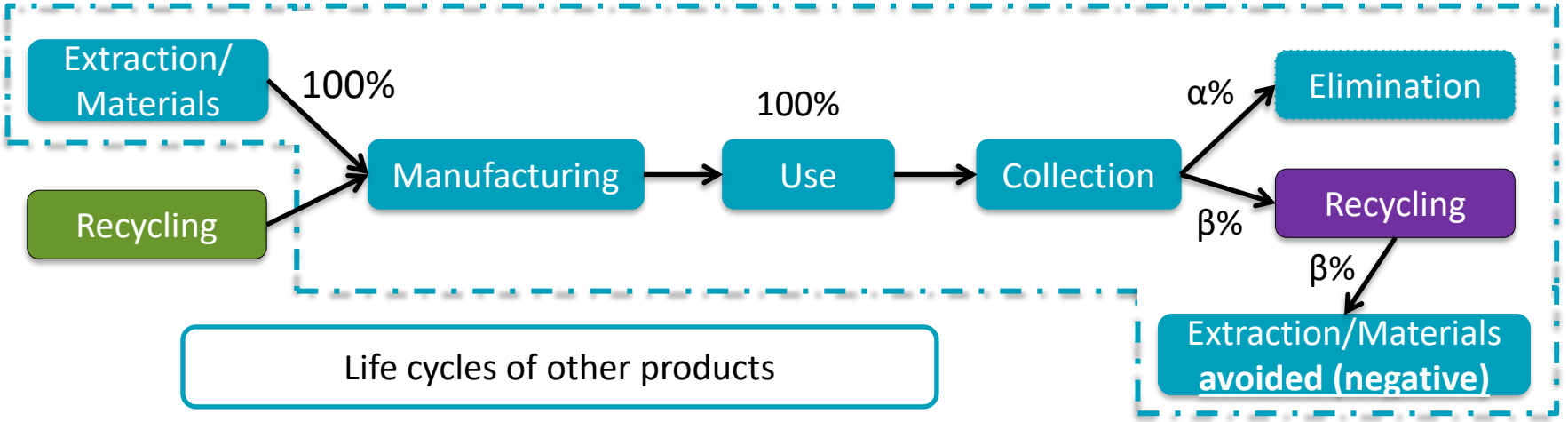
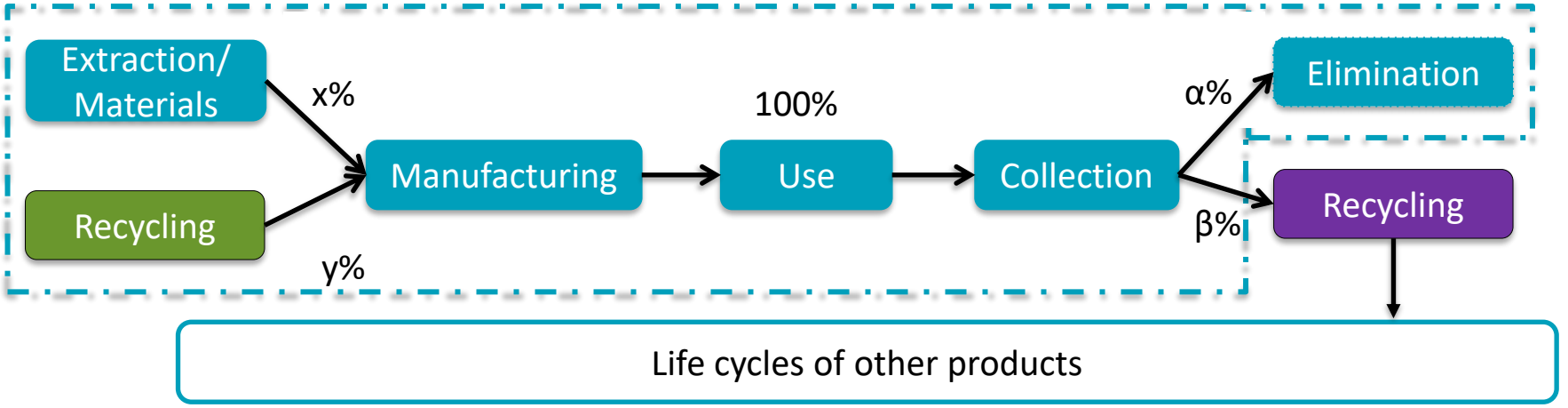
Reminder

End of life recycling



Recycled content approach



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Hand calculation: 100% primary / 75% Recycling

QUESTION 1

Question 1

Adapt the process tree to integrate the recycling of the can (100% primary / 75% recycling) and calculate the new carbon footprint according to:

i) End of life recycling approach

ii) Recycled content approach

Data

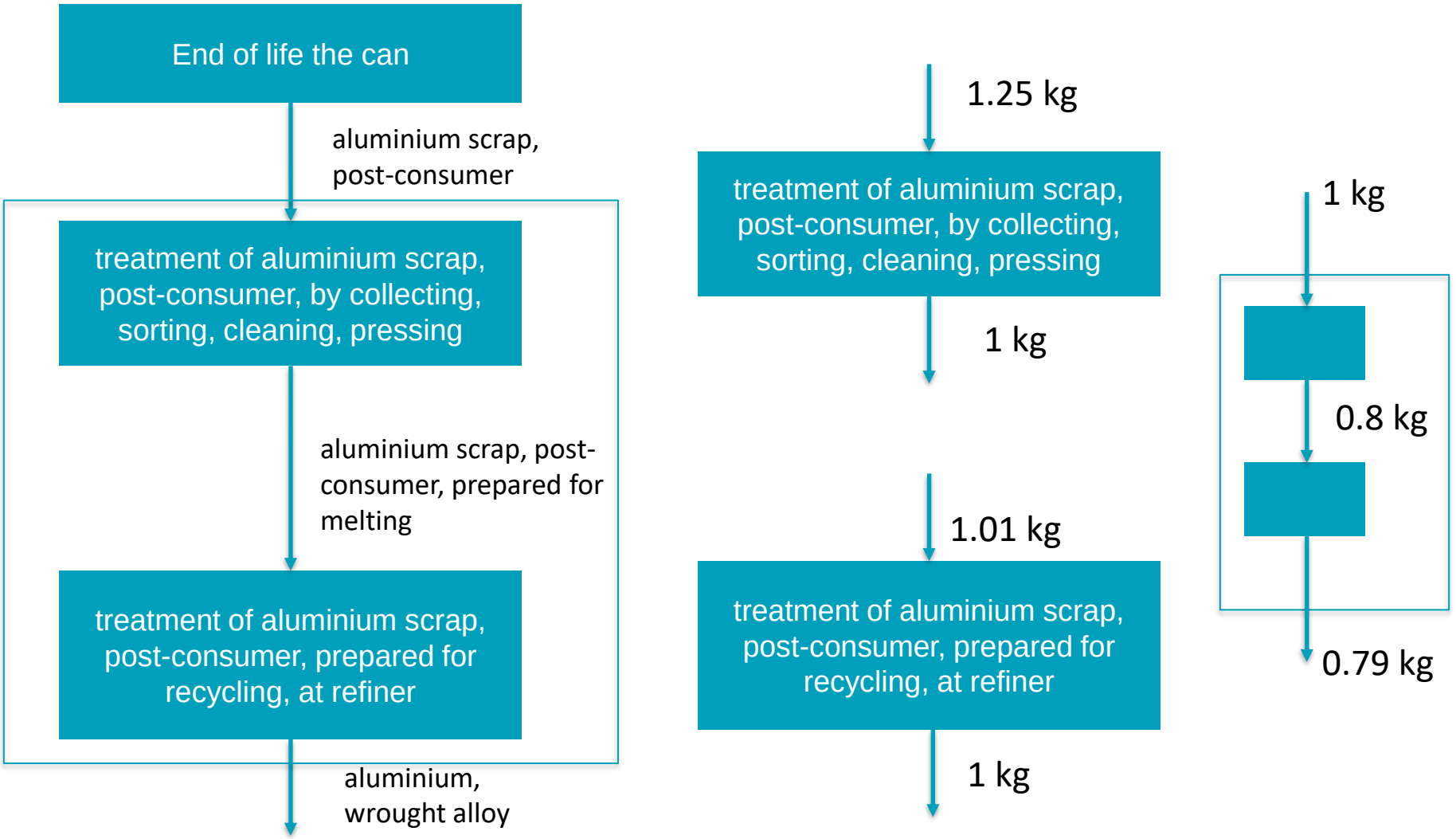
- Mass of an empty can: 13 g
- Can is made form 100% primary aluminium
- 75% of the cans are recycled
- The yield of the collecting sorting and cleaning process is 80%
- The yield of the recycling process is 99%
- The GWP of CH_4 is 29.7 kg CO_2e / kg CH4

Process	Elementery flow		Unit
	CO2	CH4	
Primary aluminium	1.06E+01	1.72E-02	kg/kg aluminium
Collecting, sorting and cleaning of aluminium scrap	2.96E-01	9.24E-03	kg/kg aluminium
Aluminium recycling	9.58E-01	2.21E-02	kg/kg aluminium
Landfill	2.32E-02	9.8E-04	kg/kg waste

Lab 1 results

Stage	Flow	kg COeq	Total
Can production	aluminium, primary, ingot	1.45E-01	
	natural gas, high pressure	1.34E-03	
	electricity, high voltage	7.31E-03	
	Carbon dioxide, fossil	5.70E-03	1.59E-01
Filling of the can	Tap water	3.72E-04	
	electricity, high voltage	2.19E-03	
	carbon dioxide, liquid	1.72E-02	
	transport, freight, lorry, unspecified	7.43E-03	2.72E-02
Cooling of the can	Refrigerator	3.45E-04	
	electricity, low voltage	1.60E-03	1.94E-03
End of life	transport, freight, lorry, unspecified	2.64E-03	
	municipal solid waste	1.24E-02	1.51E-02
		Total	**0.203453**

Question 1 – Yield calculations



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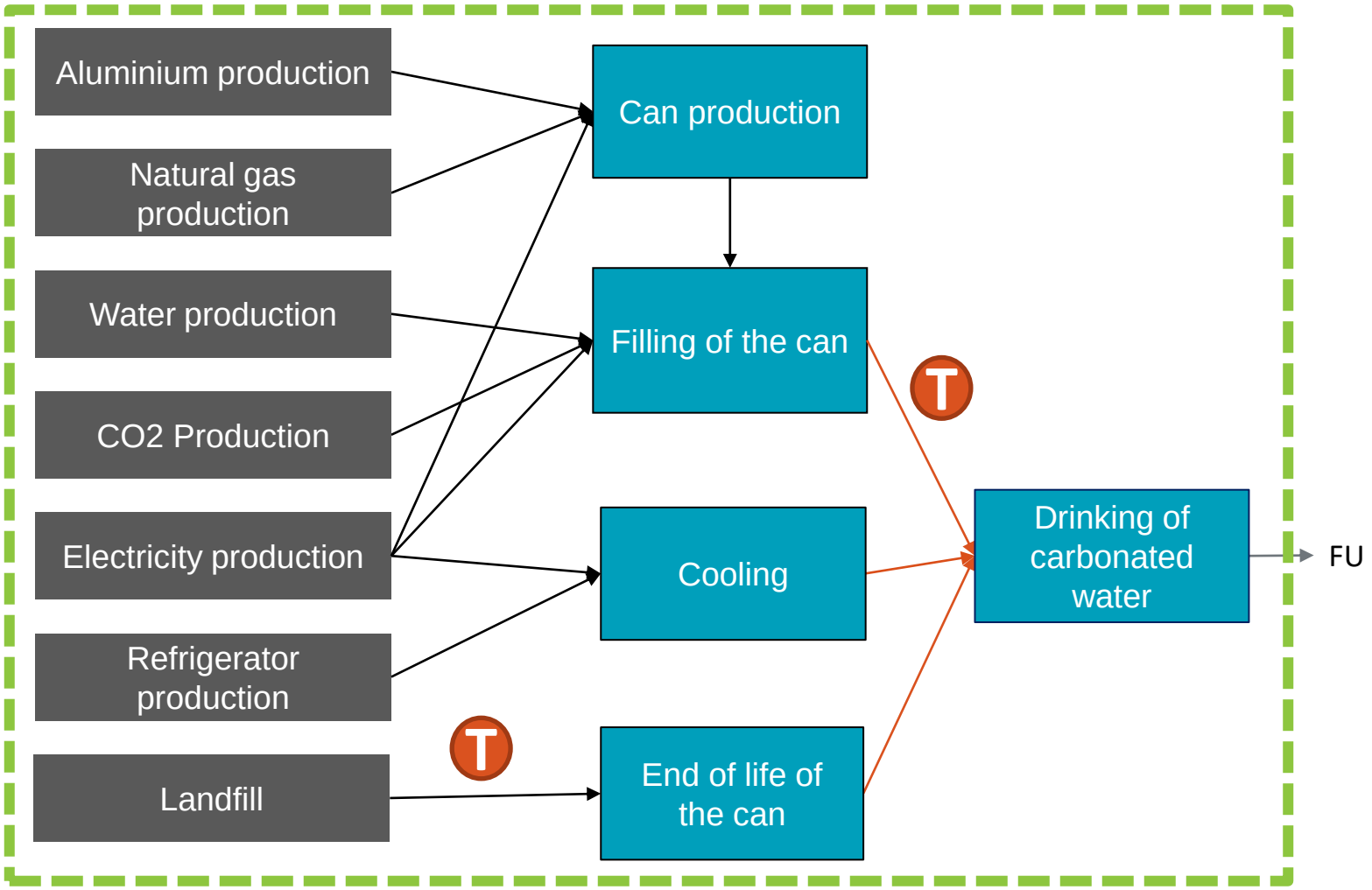
Question 1 – Process tree from previous lab



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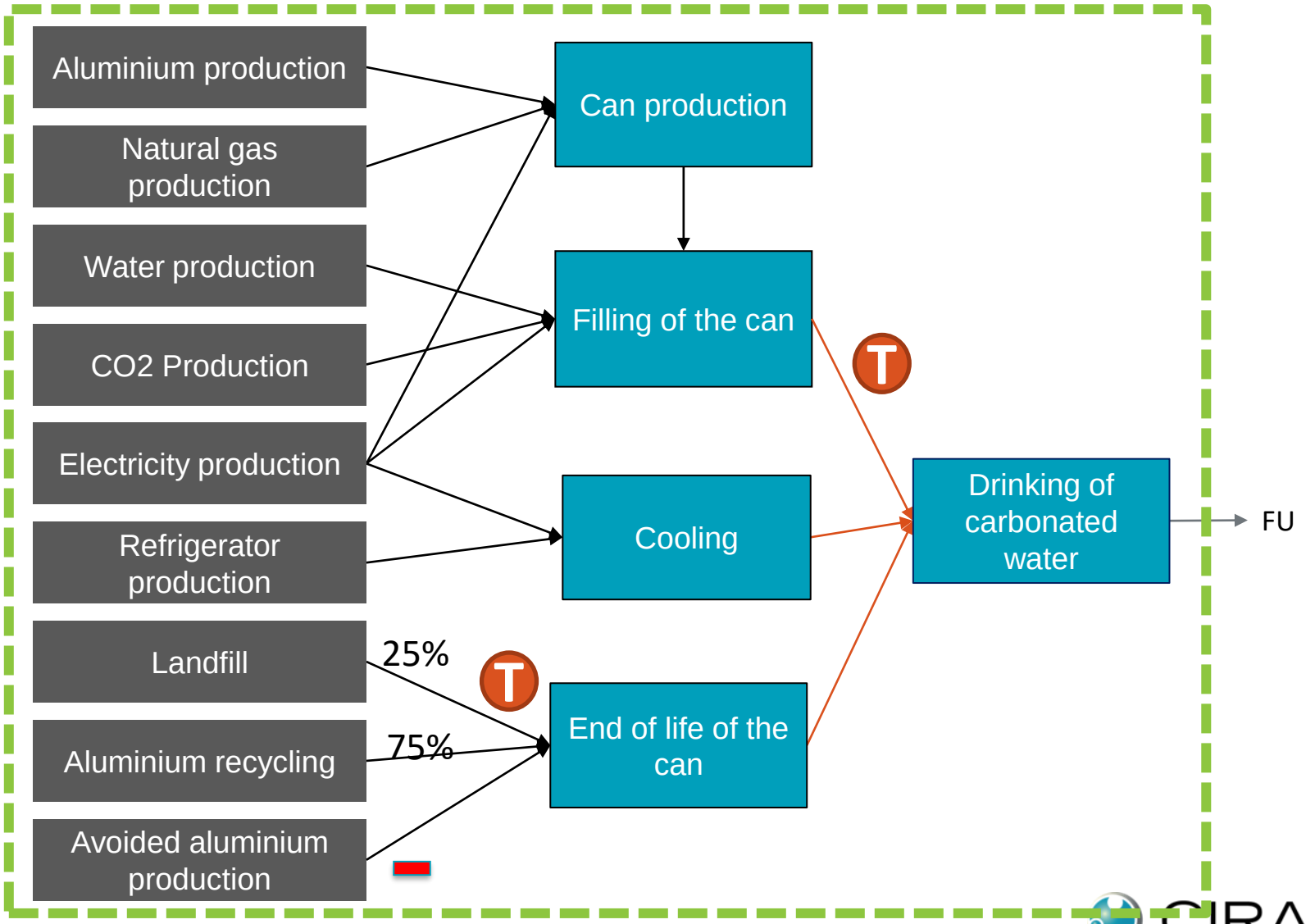
Question 1 – Process tree - End of life recycling approach



Question 1 – Calculation - End of life recycling approach

Firstly, we need to calculate the amount of landfilled aluminium

Landfill

$$landfilled\ aluminium = 13g * (1 - 0.75) * \frac{1\ kg}{1000\ g} = 0.00325\ kg\ waste$$

Recycling of aluminium

$$recycled\ aluminium = 13g * 0.75 * \frac{1\ kg}{1000\ g} = 0.00975\ kg\ recycled\ aluminium$$

Secondly, we need to calculate the amount of aluminium output from the recycling process because of the yield and efficiency of the collect and the reycling process

Avoided primary aluminium

$$aluminium\ output\ from\ recycling = 0.00975 * 0.79 = 0.007722\ kg\ of\ recycled\ Al$$

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Question 1 – Calculation - End of life recycling approach

Finaly we calculate the carbon footprint of all processes:

Landfill:

$$\frac{3.25}{1000}\ kg\ landfilled\ aluminium \times \left((0.0232) + (0.00098)\ \times 29.7\right) = 3.11E{-}03\,kg\ CO2e$$

Collect and sorting:

$$\frac{9.75}{1000}\ kg\ al\ sorted\ and\ collected \times \left((0.29623) + (0.00924) \times 29.7\right) = 5.56\mathrm{E} - 03\ kg\ CO2e$$

Recycling:

$$\frac{7.8}{1000}\ kg\ recycled\ al \times \left((0.958\ ) + (0.0221\ )\ \times 29.7\right) = 6.11\mathrm{E} - 03\ \ kg\ CO2e$$

Primary aluminium:

$$\frac{7.72}{1000}\ kg\ primary\ al \times \left(-\left((10.6) + (0.0172\ ) \times 29.7\right)\right)\ = -8.61E - 02\ kg\ CO2e$$

And recalculate the overall carbon footprint with the changes

Total: ***0.11709 kg CO2e***

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Question 1 – Calculation - End of life recycling approach

Stage	Flow	kg CO2 eq	
Can production	aluminium, primary, ingot	1.45E-01	
	natural gas, high pressure	1.34E-03	
	electricity, high voltage	7.31E-03	
	Carbon dioxide, fossil	5.70E-03	1.59E-01
Filling of the can	Tap water	3.72E-04	
	electricity, high voltage	2.19E-03	
	carbon dioxide, liquid	1.72E-02	
	transport, freight, lorry, unspecified	7.43E-03	2.72E-02
Cooling of the can	Refrigerator	3.45E-04	
	electricity, low voltage	1.60E-03	1.94E-03
End of life	transport, freight, lorry, unspecified	2.64E-06	
	municipal solid waste	3.11E-03	
	aluminium scrap, post-consumer, prepared for melting	5.56E-03	
	aluminium recycling	6.11E-03	
	aluminium, primary, ingot	-8.61E-02	-7.13E-02
	Total	**0.117**	

Carbon footprint form lab 1: 0.203 kg CO2 / kg

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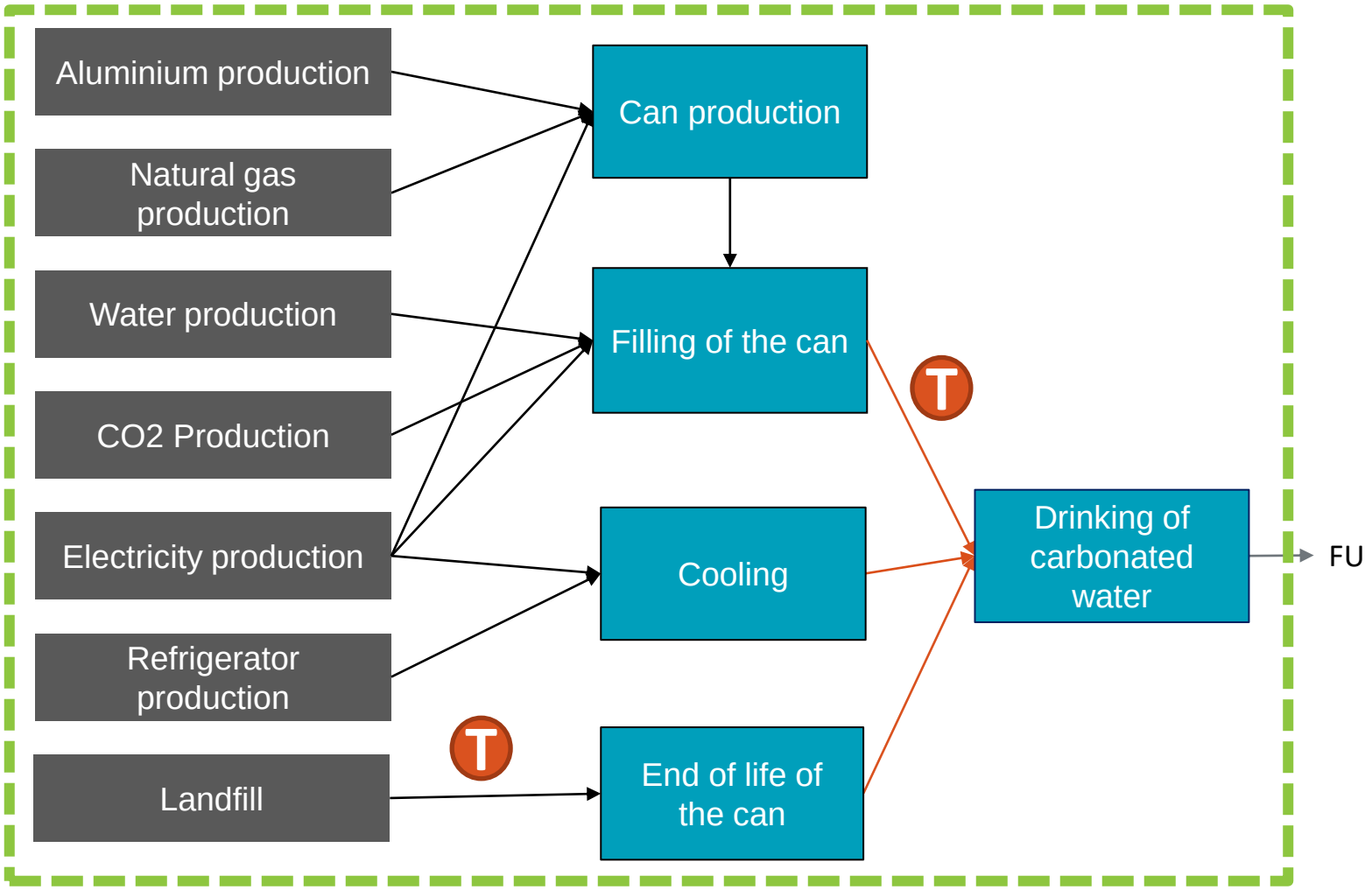
Question 1 – Process tree from previous lab



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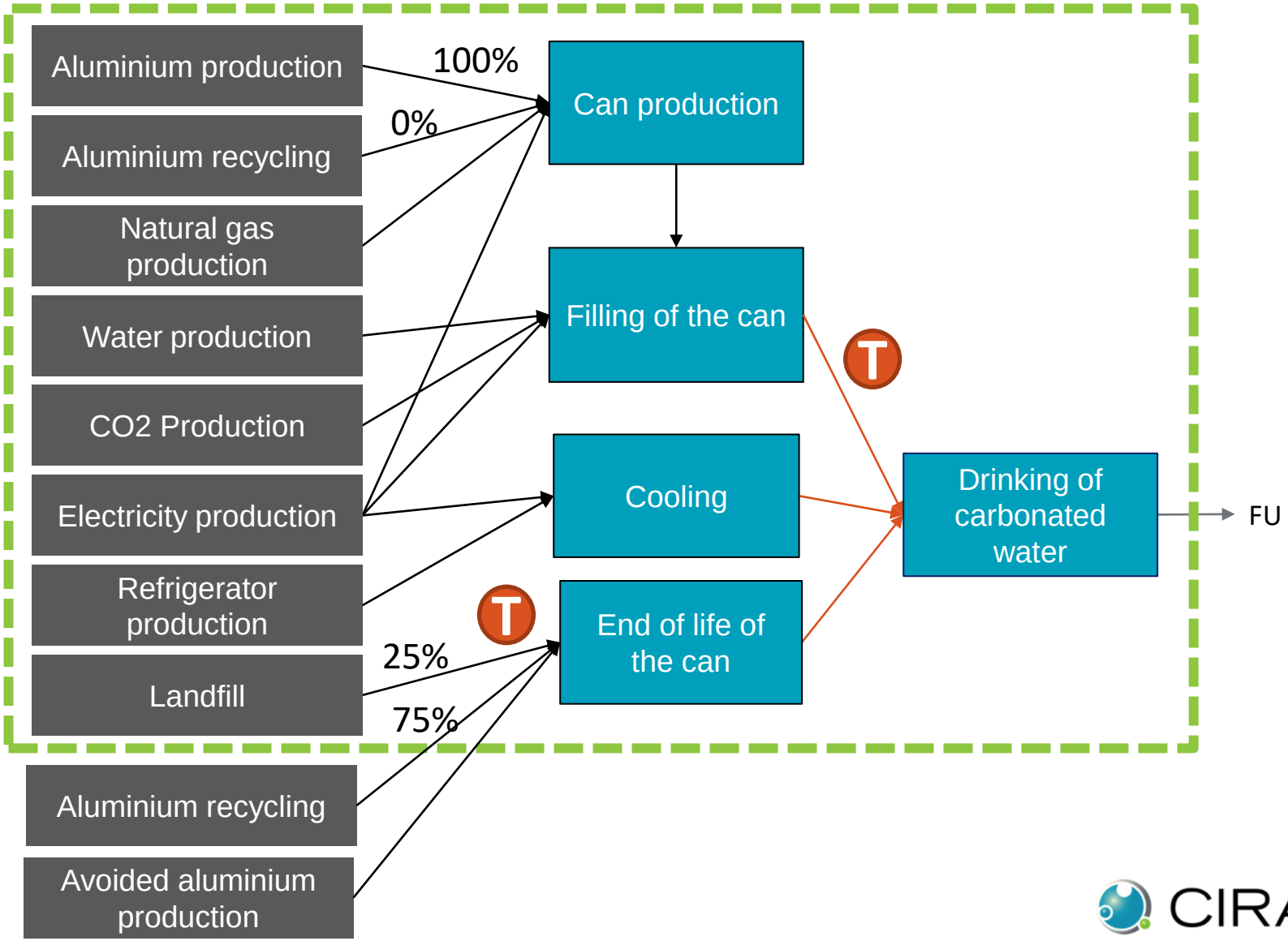
Question 1 – Process tree – Recycled content approach



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Question 1 – Calculation – Recycled content

For this approach, only the landfill process is inside the boundaries of the system. The carbon footprint is simply:

$$\frac{3.25}{1000} kg\ landfilled\ al \times \big((0.09365) + (0.02907)\ \times 29.7\big) = 3.11E{-}03\ kg\ CO2e$$

Landfill

For an overall carbon footprint of : 0.19412 kg CO2

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Question 1 – Calculation – Recycled content

Stage	Flow	kg CO2 eq	
Can production	aluminium, primary, ingot	1.45E-01	
	natural gas, high pressure	1.34E-03	
	electricity, high voltage	7.31E-03	
	Carbon dioxide, fossil	5.70E-03	1.59E-01
Filling of the can	Tap water	3.72E-04	
	electricity, high voltage	2.19E-03	
	carbon dioxide, liquid	1.72E-02	
	transport, freight, lorry, unspecified	7.43E-03	2.72E-02
Cooling of the can	Refrigerator	3.45E-04	
	electricity, low voltage	1.60E-03	1.94E-03
End of life	transport, freight, lorry, unspecified	2.64E-03	
	municipal solid waste	3.11E-03	5.75E-03
	Total	**0.19412**	

Calculation by hand: 60% primary / 75% recycling

QUESTION 2

Question 2

Adapt the process tree to integrate the recycling of the can (60% primary / 75% recycling and calculate the new carbon footprint according to:

i) End of life recycling approach

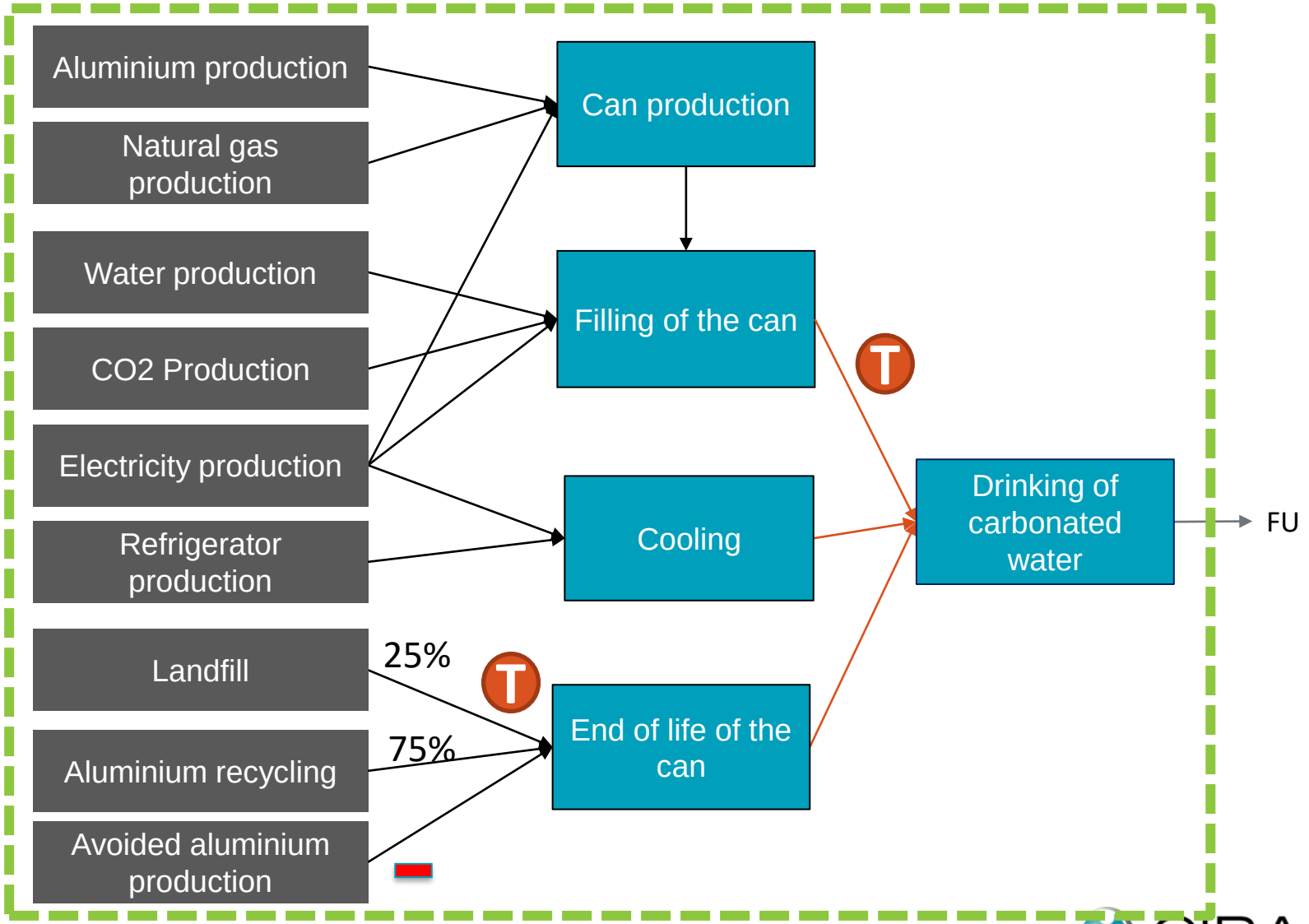
ii) Recycled content approach

Data:

- Mass of an empty can: 13 g
- Can is made form 60% primary aluminium
- 75% of the cans are recycled
- The yield of the collecting sorting and cleaning process is 80%
- The yield of the recycling process is 99%
- PRG of CH_4 is 29.7 kg CO_2e / kg

Process	Elementery flow		Unit
	CO2	CH4	
Primary aluminium	1.37E+01	1.58E-02	kg/kg aluminium
Collecting, sorting and cleaning of aluminium scrap	0.29623	0.00924	kg/kg aluminium
Aluminium recycling	9.58 E-01	2.21 E-02	kg/kg aluminium
Landfill	2.32 E-02	9.8 E-04	kg/kg waste

Question 2 - Process tree - End of life recycling approach



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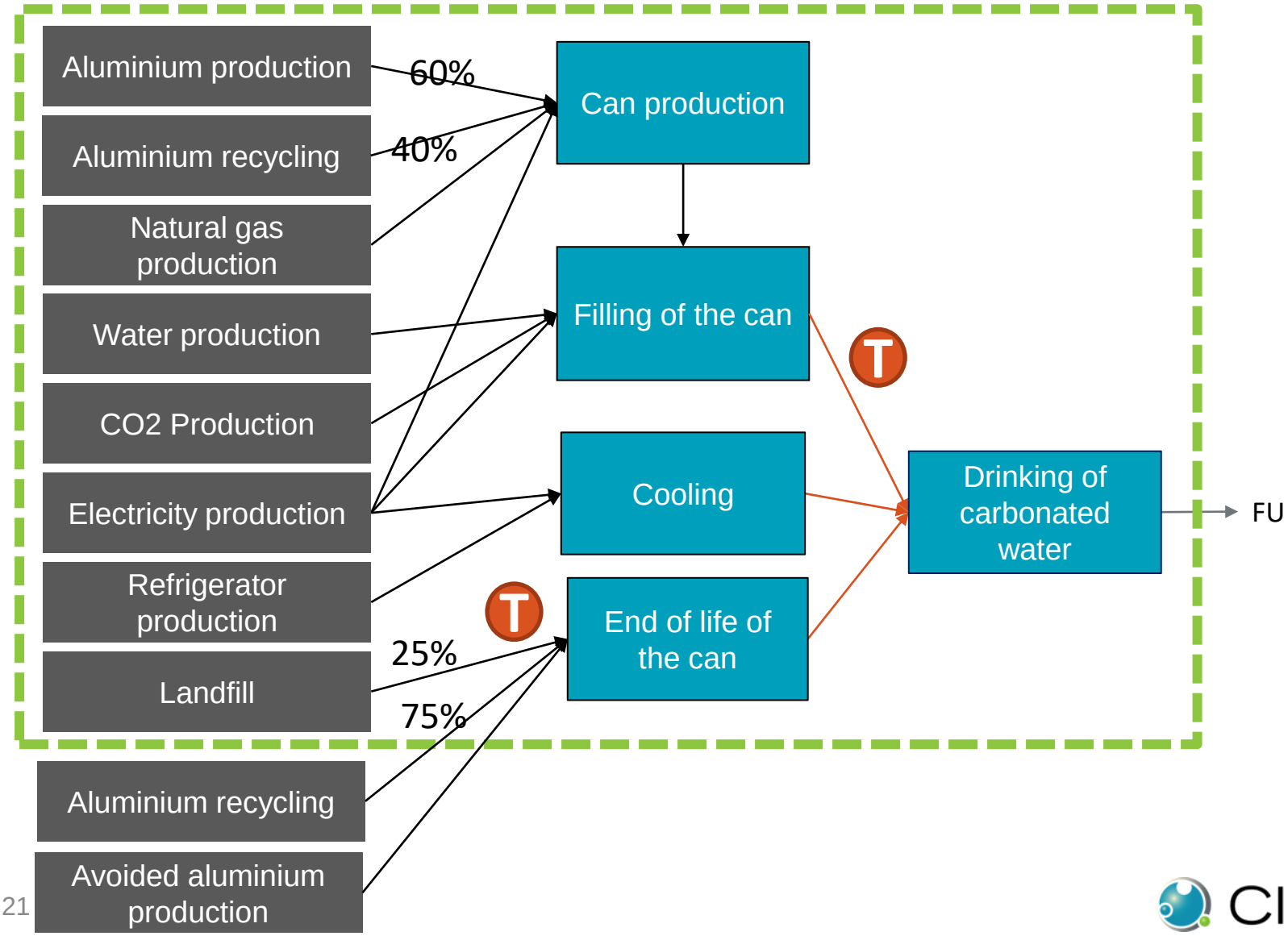
Question 2 - Process tree - End of life recycling approach

The end of life recycling approach assumes a 100% of primary content.

There is no change for this situation

Total: ***0.11709 kg CO2e***

Question 2 – Process tree – Recycled content approach



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Question 2 – Process tree – Recycled content approach

The calculation of the end of life is the same as Question 1

$$\mathbf{1.487\ E-4\ kg\ CO2e}$$

But we do need to change the impact from the can production

Production of primary aluminium

$$0.013\ kg\ primary\ al\ \times 0.6\ \times ((10.64\ ) + (0.0172)\ \times 29.7) = \mathbf{8.69E-02\ kg\ CO2e}$$

Production recycled aluminium:

$$0.013\ kg\ recycled\ al \times 0.4\ \times ((0.74134) + (0.00143\ )\ \times 29.7) = \mathbf{2.55E-03kg\ CO2e}$$

The total carbon footprint of the can production according the recycled content approach is:

0.13746 kg CO_{2e}

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Question 2 – Calculation – Recycled content

Stage	Flow	kg CO2 eq	
Can production	aluminium, primary, ingot	8.69E-02	1.04E-01
	aluminium, wrought alloy (from recycling)	4.08E-03	
	natural gas, high pressure	1.34E-03	
	electricity, high voltage	7.31E-03	
	Carbon dioxide, fossil	5.70E-03	
Filling of the can	Tap water	3.72E-04	2.72E-02
	electricity, high voltage	2.19E-03	
	carbon dioxide, liquid	1.72E-02	
	transport, freight, lorry, unspecified	7.43E-03	
Cooling of the can	Refrigerator	3.45E-04	1.94E-03
	electricity, low voltage	1.60E-03	
End of life	transport, freight, lorry, unspecified	2.64E-03	4.50E-03
	municipal solid waste	3.11E-03	
Total		**0.14024**	

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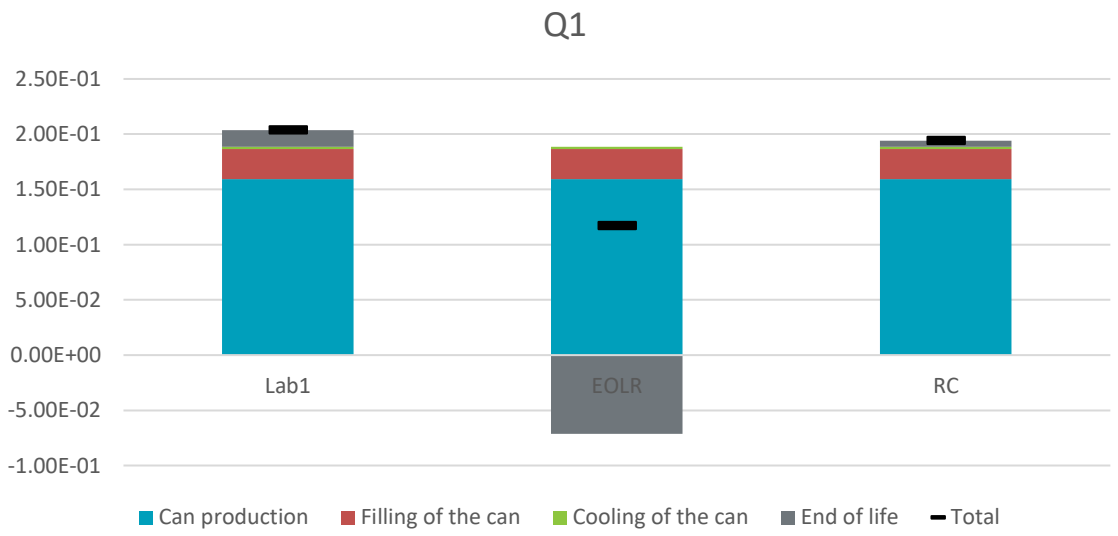
Results comparison

QUESTION 3

Question 3

Compare calculated results of Q1 to carbon footprint from lab1

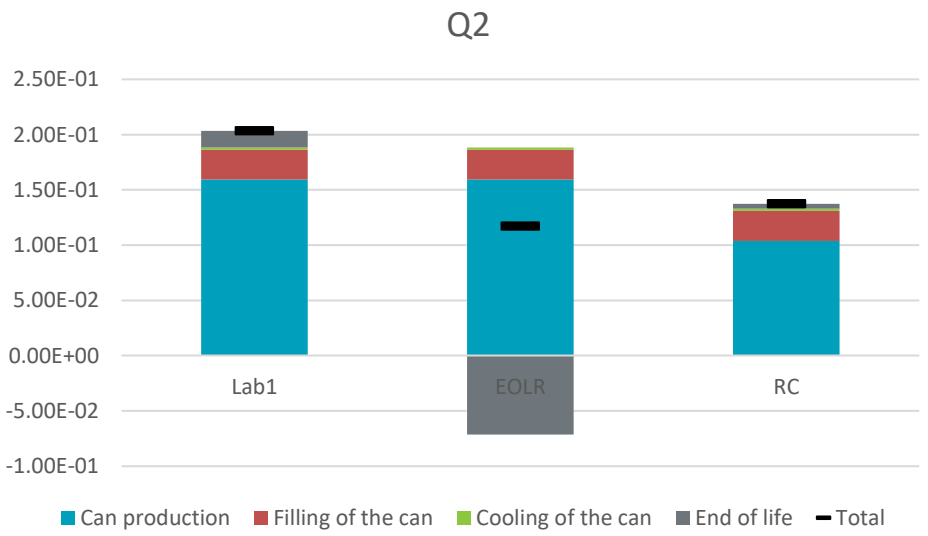
	Q1		
	Lab1	EOLR	RC
Can production	1.59E-01	1.59E-01	1.59E-01
Filling of the can	2.72E-02	2.72E-02	2.72E-02
Cooling of the can	1.94E-03	1.94E-03	1.94E-03
End of life	1.51E-02	-7.13E-02	5.75E-03
Total	2.03E-01	1.17E-01	1.94E-01



Question 3

Compare calculated results of Q2 to carbon footprint from lab1

	Q2		
	Lab1	EOLR	RC
Can production	1.59E-01	1.59E-01	1.04E-01
Filling of the can	2.72E-02	2.72E-02	2.72E-02
Cooling of the can	1.94E-03	1.94E-03	1.94E-03
End of life	1.51E-02	-7.13E-02	4.50E-03
Total	2.03E-01	1.17E-01	1.40E-01



openLCA modelling

QUESTION 4

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Modeling steps

- Create new folders in processes folder
  - **Q1-EOLR**
  - **Q1-RC**
  - **Q2-EOLR**
  - **Q2-RC**
- Create parameters
  - **Q1_recycling_rate (75%)**
  - **Q2_recycled_content (60%)**

- Copy appropriate processes
- Adapt quantities and input
- Creat new product systems
- Calcualte results

Flow	Process
aluminium scrap, post-consumer, prepared for melting	aluminium scrap, post-consumer, prepared for melting, Recycled Content cut-off | aluminium scrap, post-consumer, prepared for melting | Cutoff, S - GLO
aluminium, wrought alloy	treatment of aluminium scrap, post-consumer, prepared for recycling, at remelter | aluminium, wrought alloy | Cutoff, S - RoW

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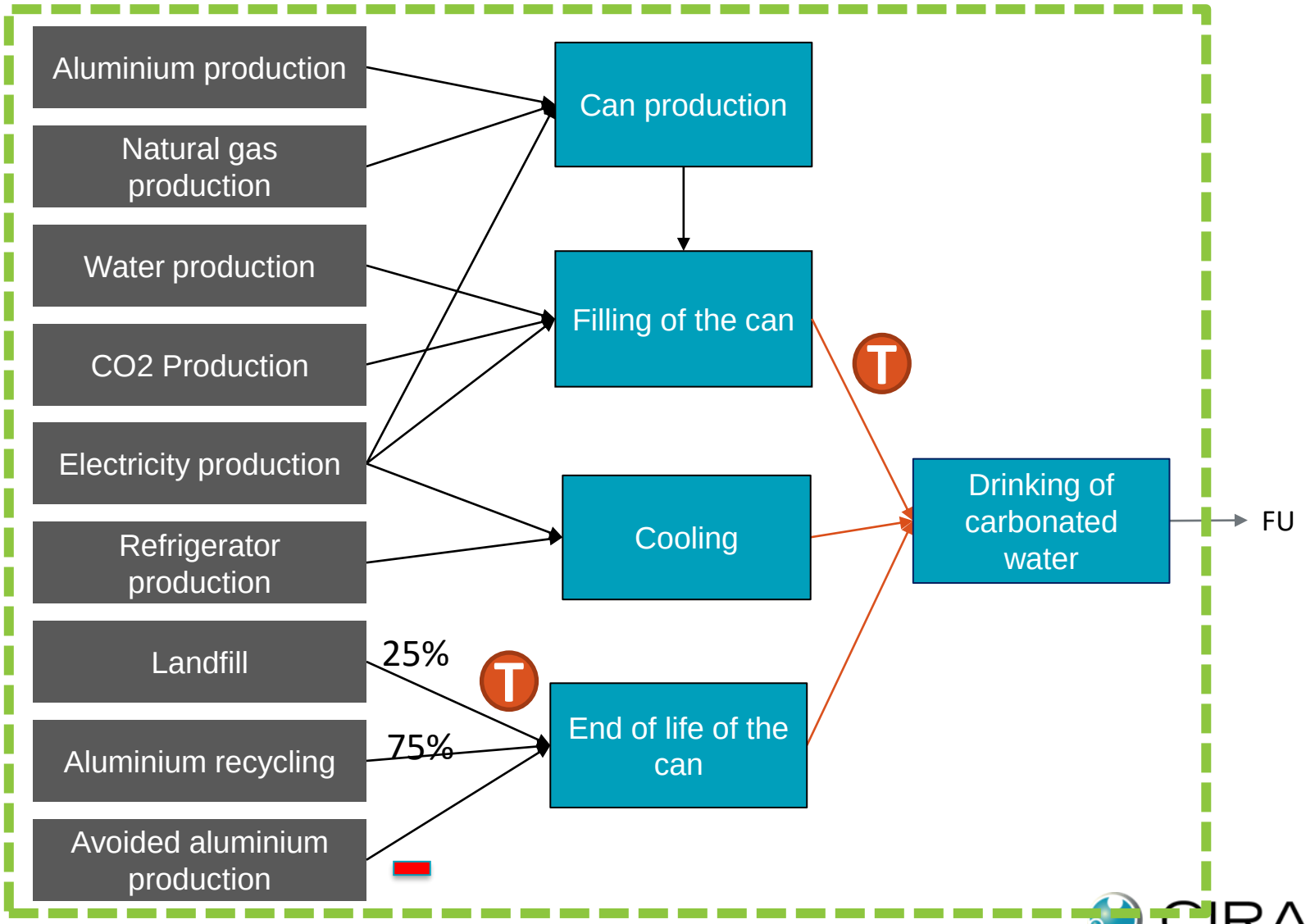
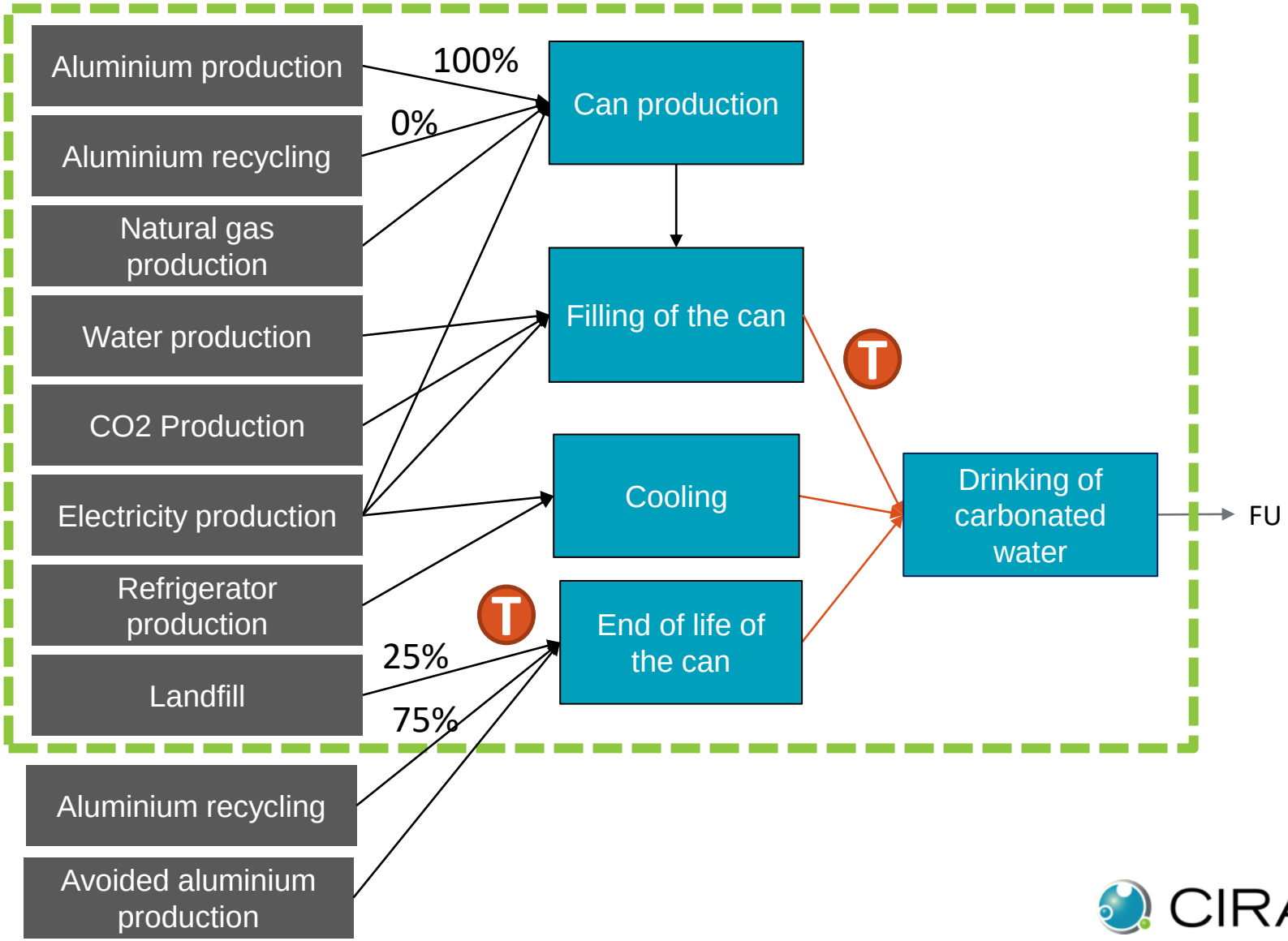
Question 1 – Process tree - End of life recycling approach



Question 1 – Process tree – Recycled content approach



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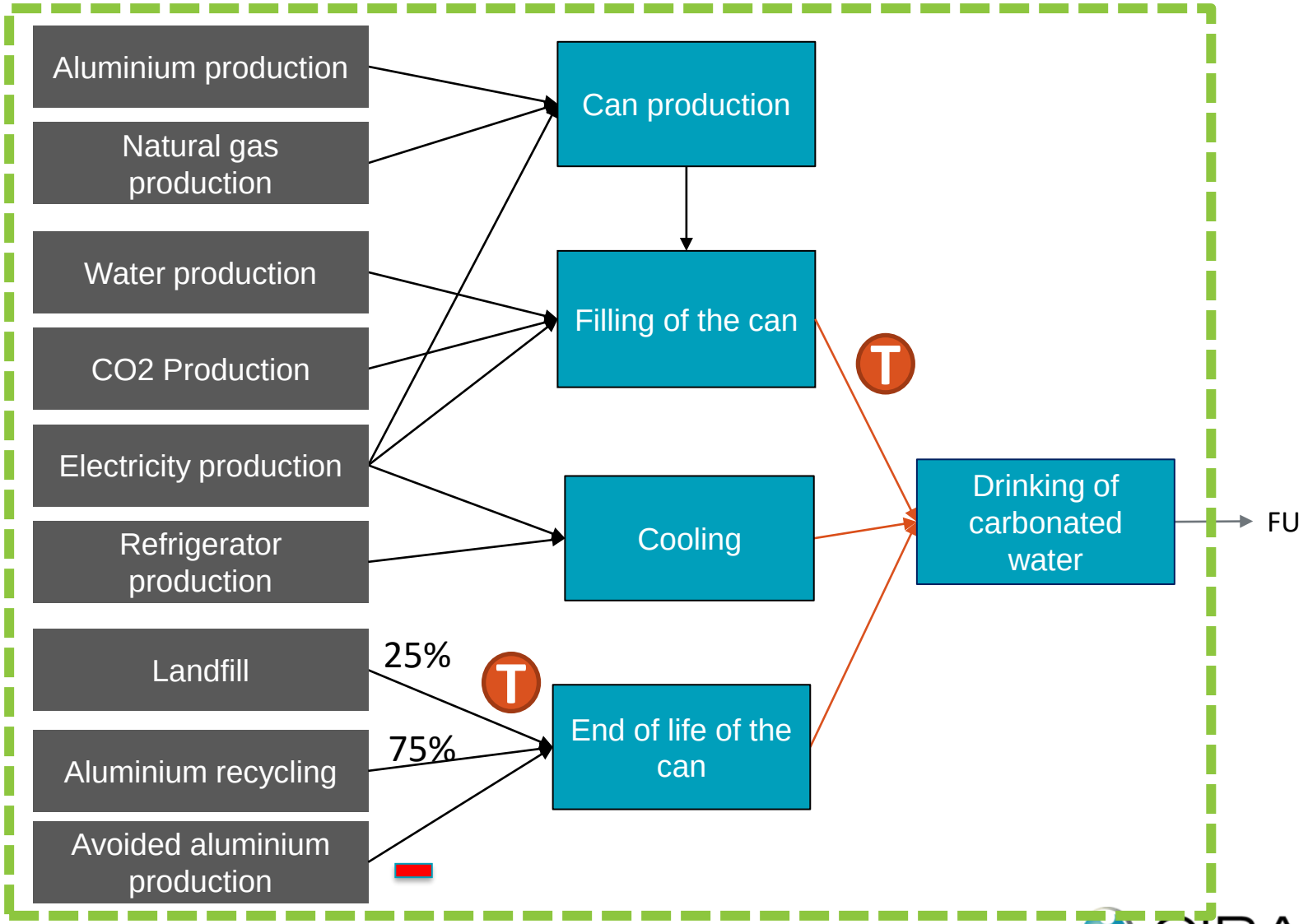
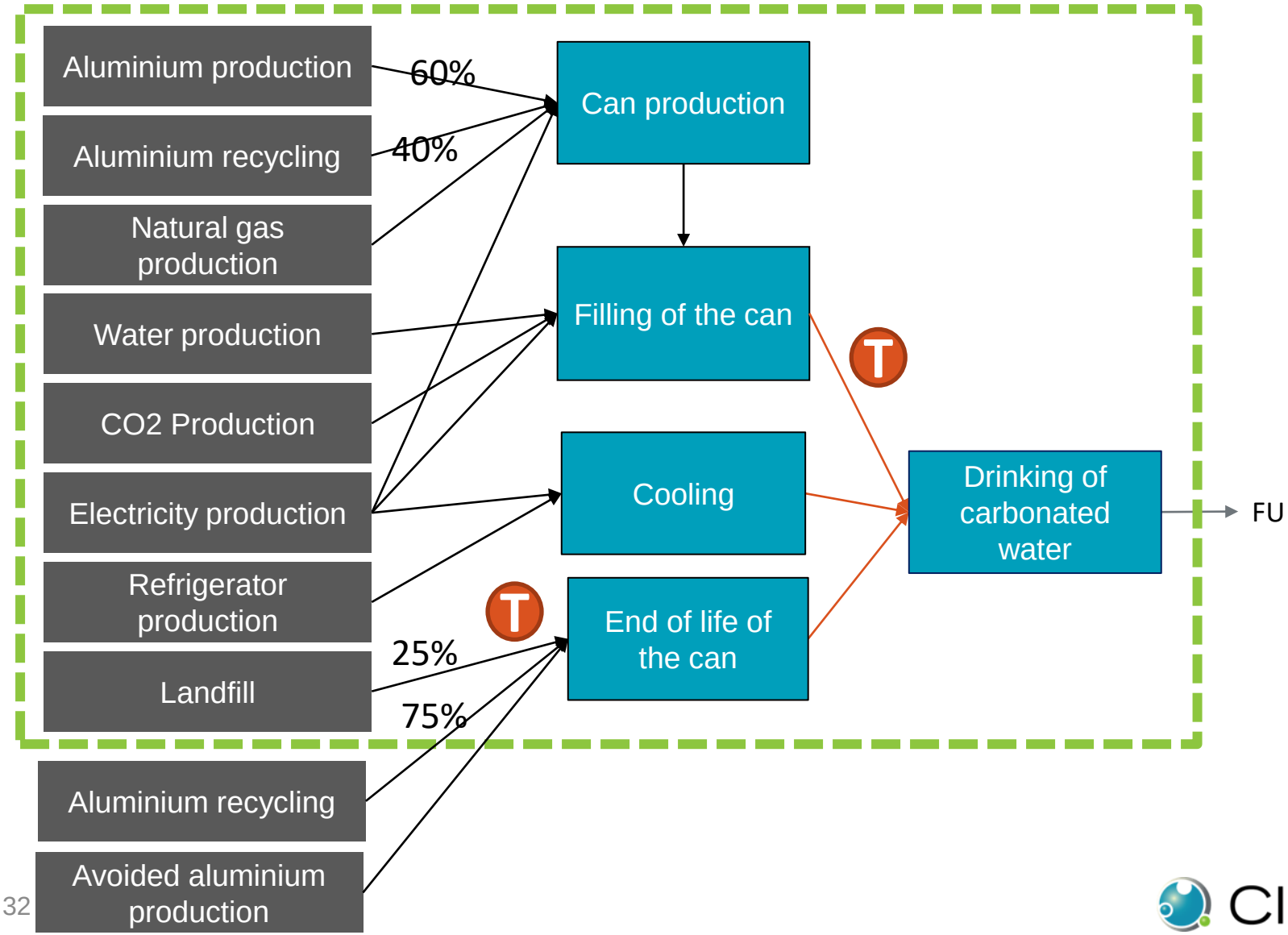
Question 2 - Process tree - End of life recycling approach



Question 2 – Process tree – Recycled content approach



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Results comparison

	Q1-EOLR	Q1-RC	Q2-EOLR	Q2-RC
By hand	0.117	0.194	0.117	0.1402
openLCA	0.1153	0.1989	0.1153	0.1404