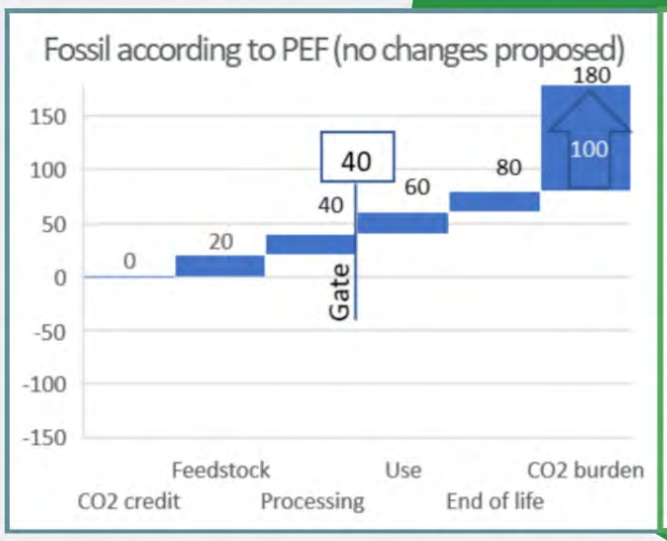
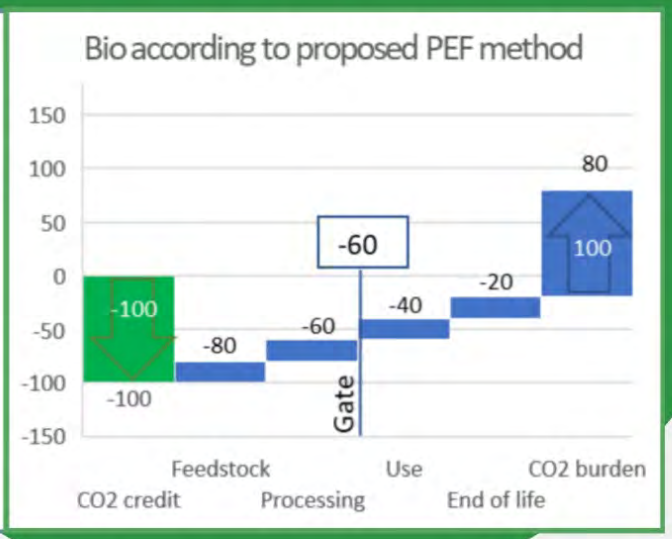
TPS與CelluPlas的減塑減碳應用

徐立偉
info@holyard.com.tw
0988-309765

TPS與CelluPlas

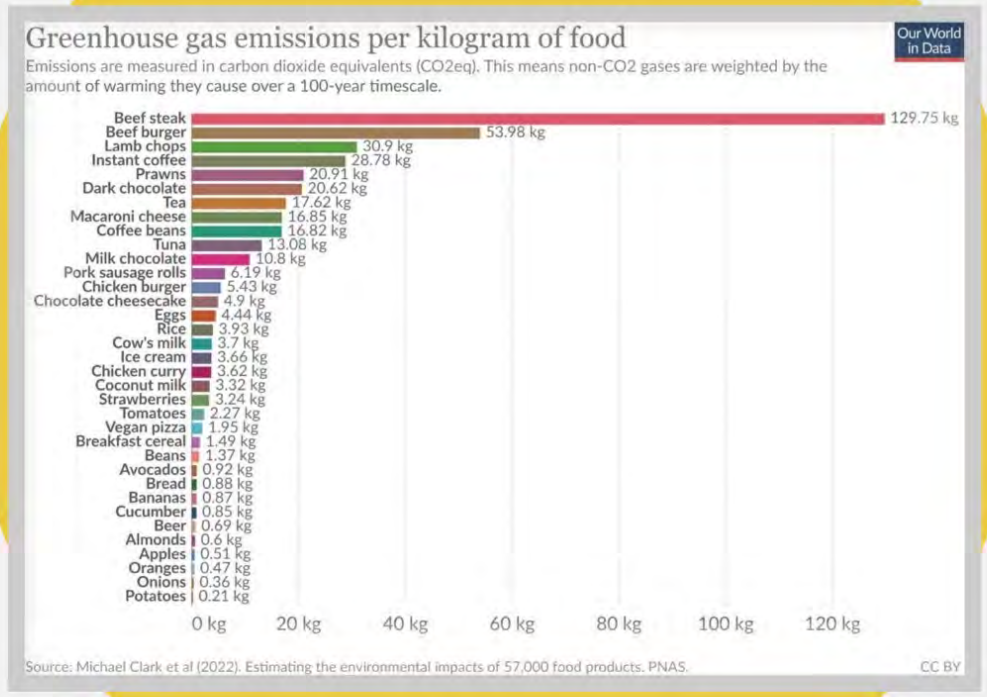


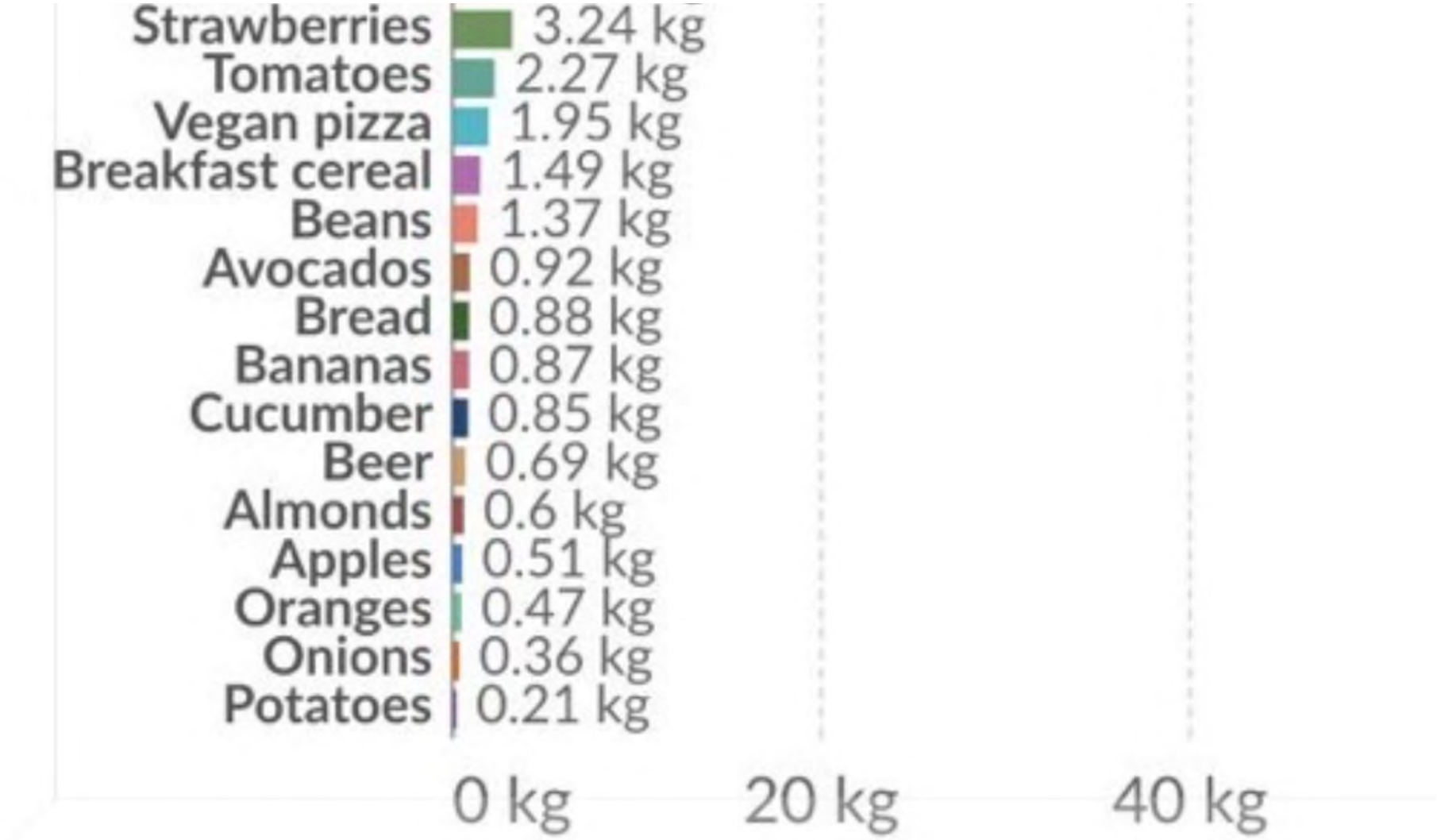


生活無處
不減碳

TPS

CelluPlas


Greenhouse gas emissions per kilogram of food
Emissions are measured in carbon dioxide equivalents (CO2eq). This means non-CO2 gases are weighted by the amount of warming they cause over a 100-year timescale.
Our World in Data
Beef steak 129.75 kg
Beef burger 53.98 kg
Lamb chops 30.9 kg
Instant coffee 28.78 kg
Prawns 20.91 kg
Dark chocolate 20.62 kg
Tea 17.62 kg
Macaroni cheese 16.85 kg
Coffee beans 16.82 kg
Tuna 13.08 kg
Milk chocolate 10.8 kg
Pork sausage rolls 6.19 kg
Chicken burger 5.43 kg
Chocolate cheesecake 4.9 kg
Eggs 4.44 kg
Rice 3.93 kg
Cow's milk 3.7 kg
Ice cream 3.66 kg
Chicken curry 3.62 kg
Coconut milk 3.32 kg
Strawberries 3.24 kg
Tomatoes 2.27 kg
Vegan pizza 1.95 kg
Breakfast cereal 1.49 kg
Beans 1.37 kg
Avocados 0.92 kg
Bread 0.88 kg
Bananas 0.87 kg
Cucumber 0.85 kg
Beer 0.69 kg
Almonds 0.6 kg
Apples 0.51 kg
Oranges 0.47 kg
Onions 0.36 kg
Potatoes 0.21 kg
0 kg
20 kg
40 kg
60 kg
80 kg
100 kg
120 kg
Source: Michael Clark et al (2022). Estimating the environmental impacts of 57,000 food products. PNAS.
CC BY


Strawberries 3.24 kg
Tomatoes 2.27 kg
Vegan pizza 1.95 kg
Breakfast cereal 1.49 kg
Beans 1.37 kg
Avocados 0.92 kg
Bread 0.88 kg
Bananas 0.87 kg
Cucumber 0.85 kg
Beer 0.69 kg
Almonds 0.6 kg
Apples 0.51 kg
Oranges 0.47 kg
Onions 0.36 kg
Potatoes 0.21 kg
0 kg
20 kg
40 kg

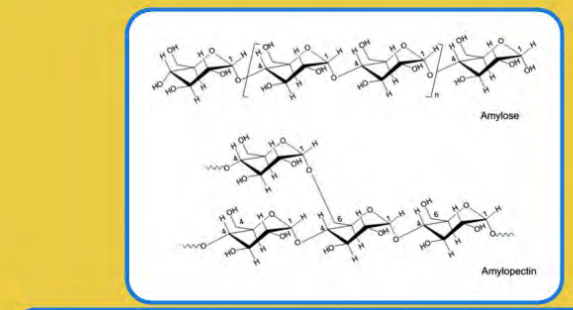
熱塑性澱粉膠粒
Thermoplstic Starch (TPS)

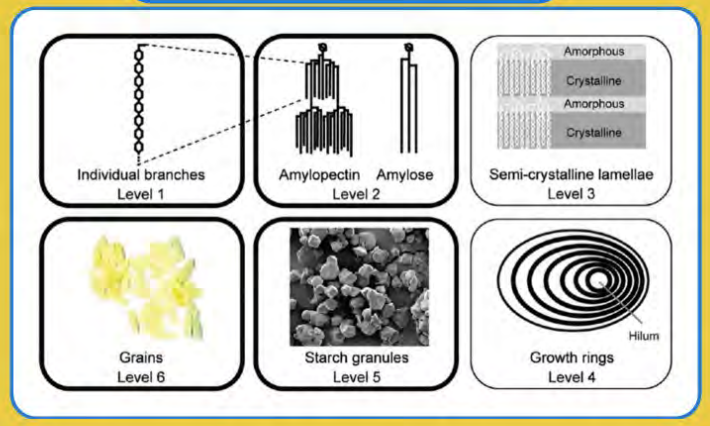
Amyloplas TPS100 Granules

TPS

核心技術

澱粉的結構

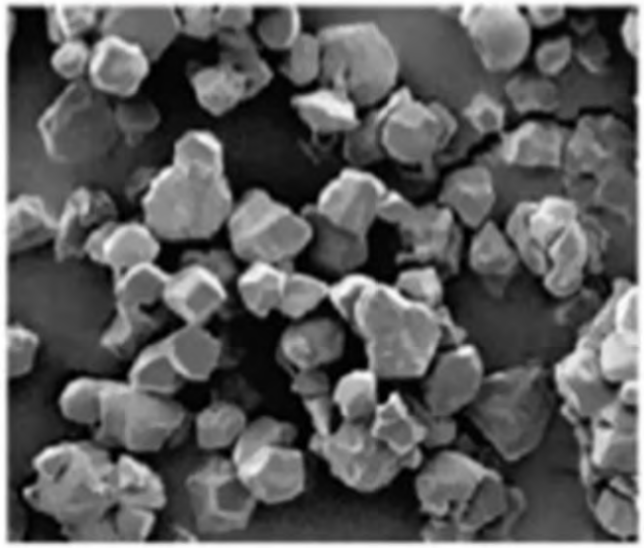

Amylose
Amylopectin


Individual branches
Level 1
Amylopectin
Amylose
Level 2
Amorphous
Crystalline
Amorphous
Crystalline
Semi-crystalline lamellae
Level 3
Grains
Level 6
Starch granules
Level 5
Hilum
Growth rings
Level 4

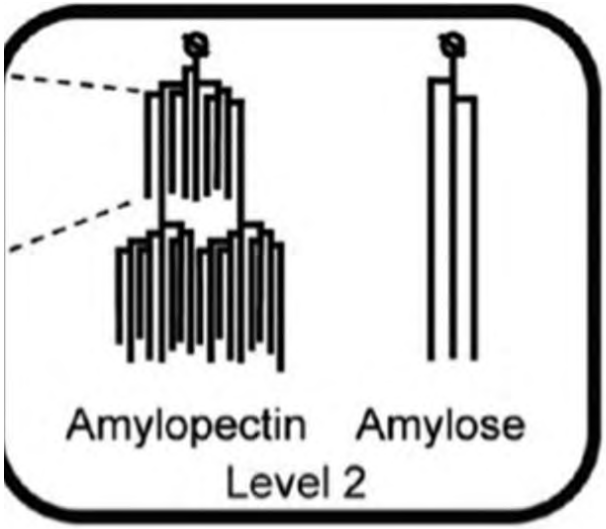
Level 1

Level 2

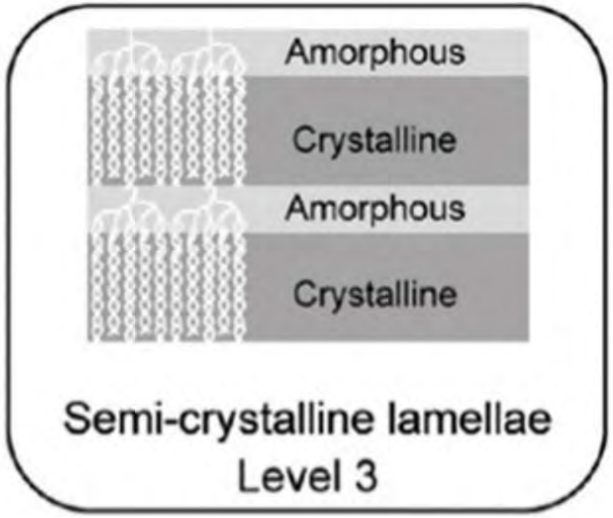
Grains
Level 6



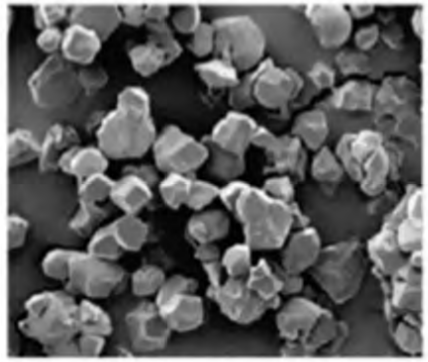
Starch granules
Level 5



Amylopectin Amylose
Level 2

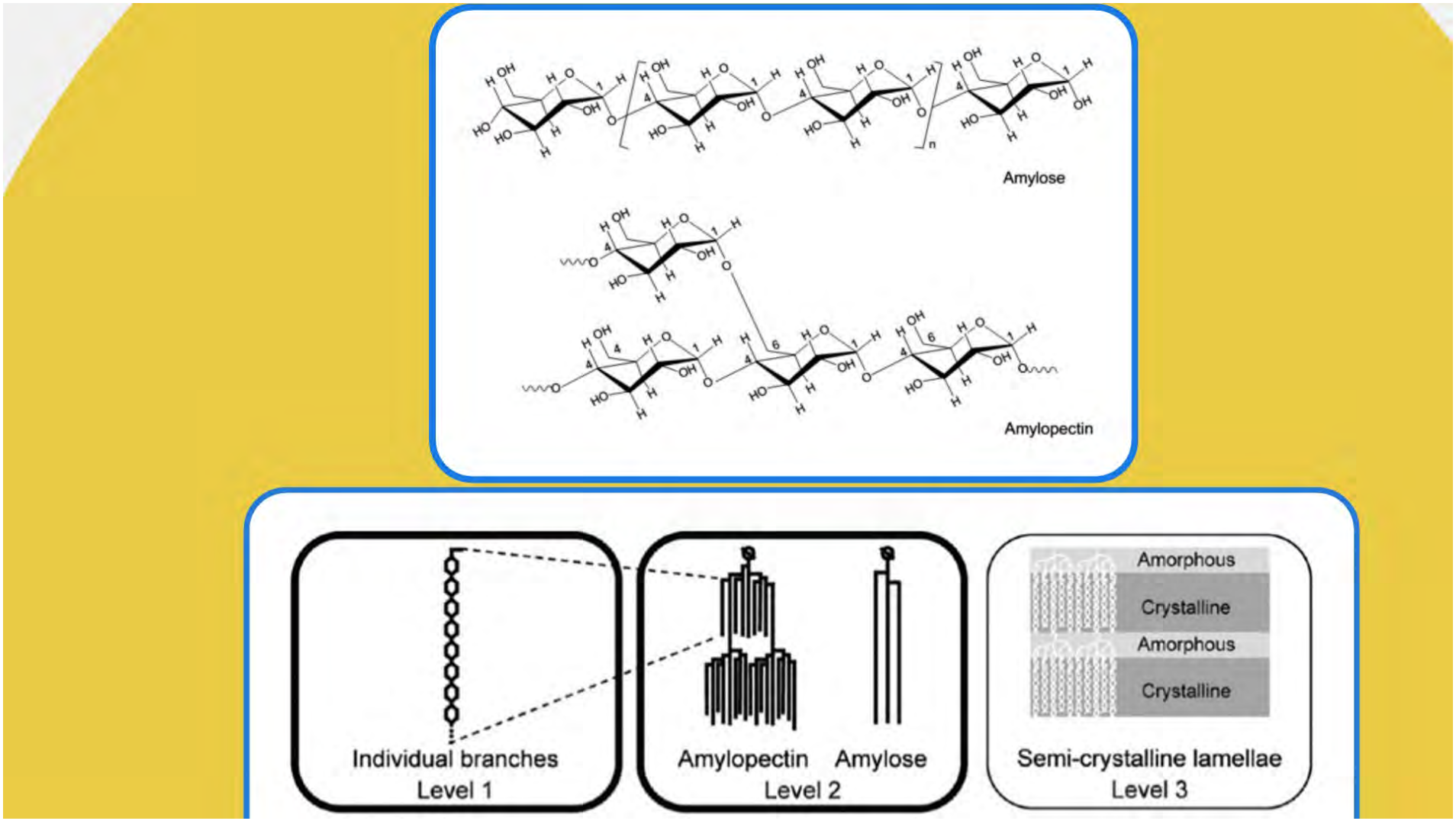


Semi-crystalline lamellae
Level 3

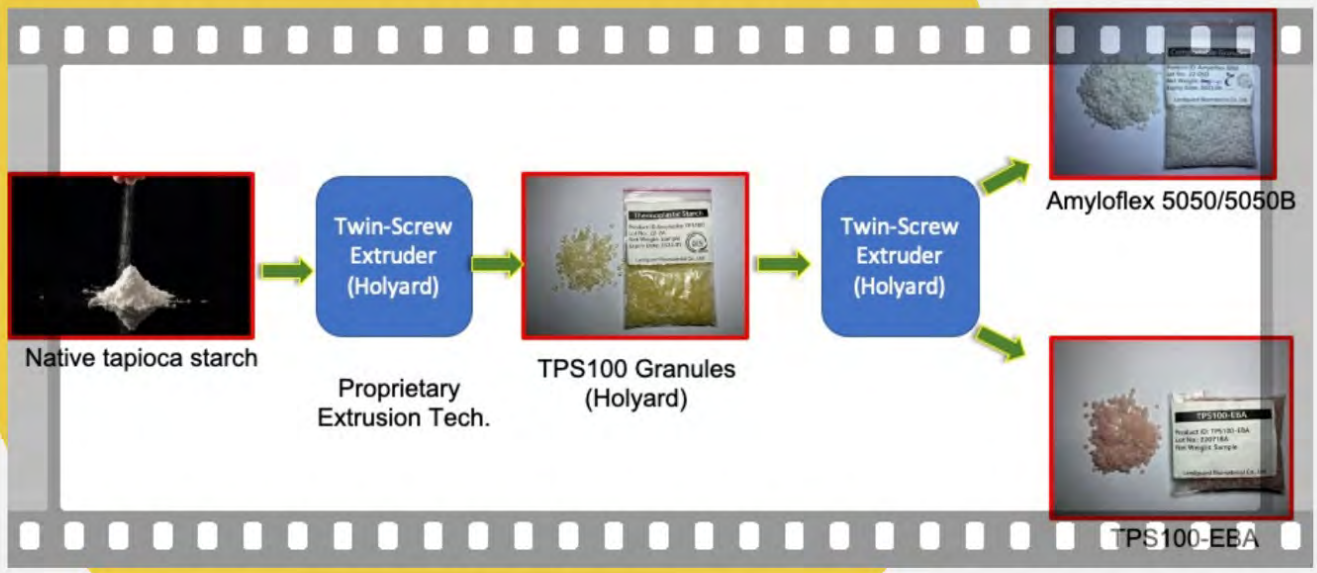


Starch granules
Level 5

Growth rings
Level 4

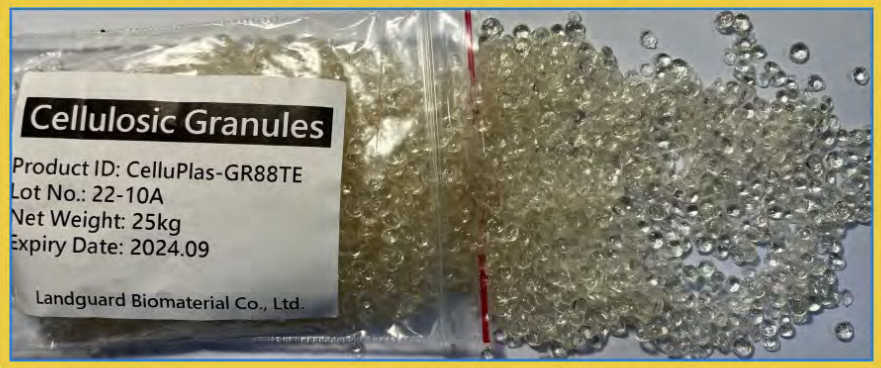

Amylose
Amylopectin
Individual branches
Level 1
Amylopectin
Amylose
Level 2
Amorphous
Crystalline
Amorphous
Crystalline
Semi-crystalline lamellae
Level 3

TPS熱熔押出及共混


Native tapioca starch
Twin-Screw Extruder (Holyard)
Proprietary Extrusion Tech.
TPS100 Granules (Holyard)
Twin-Screw Extruder (Holyard)
Amyloflex 5050/5050B
TPS100-EBA

CelluPlas Granules (Cellulose Acetate) 醋酸纖維素膠粒

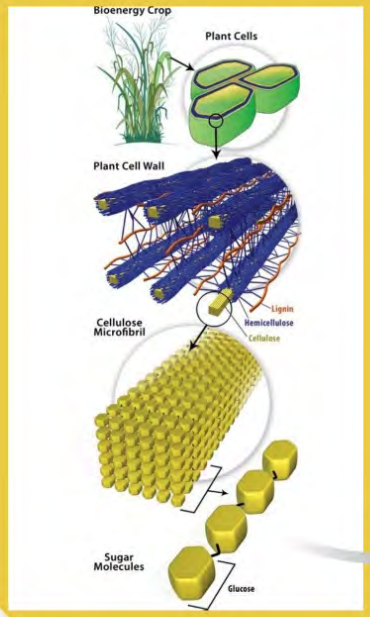
CelluPlas GR88TE

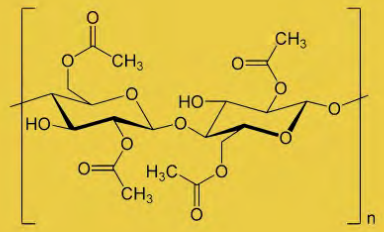


CelluPlas

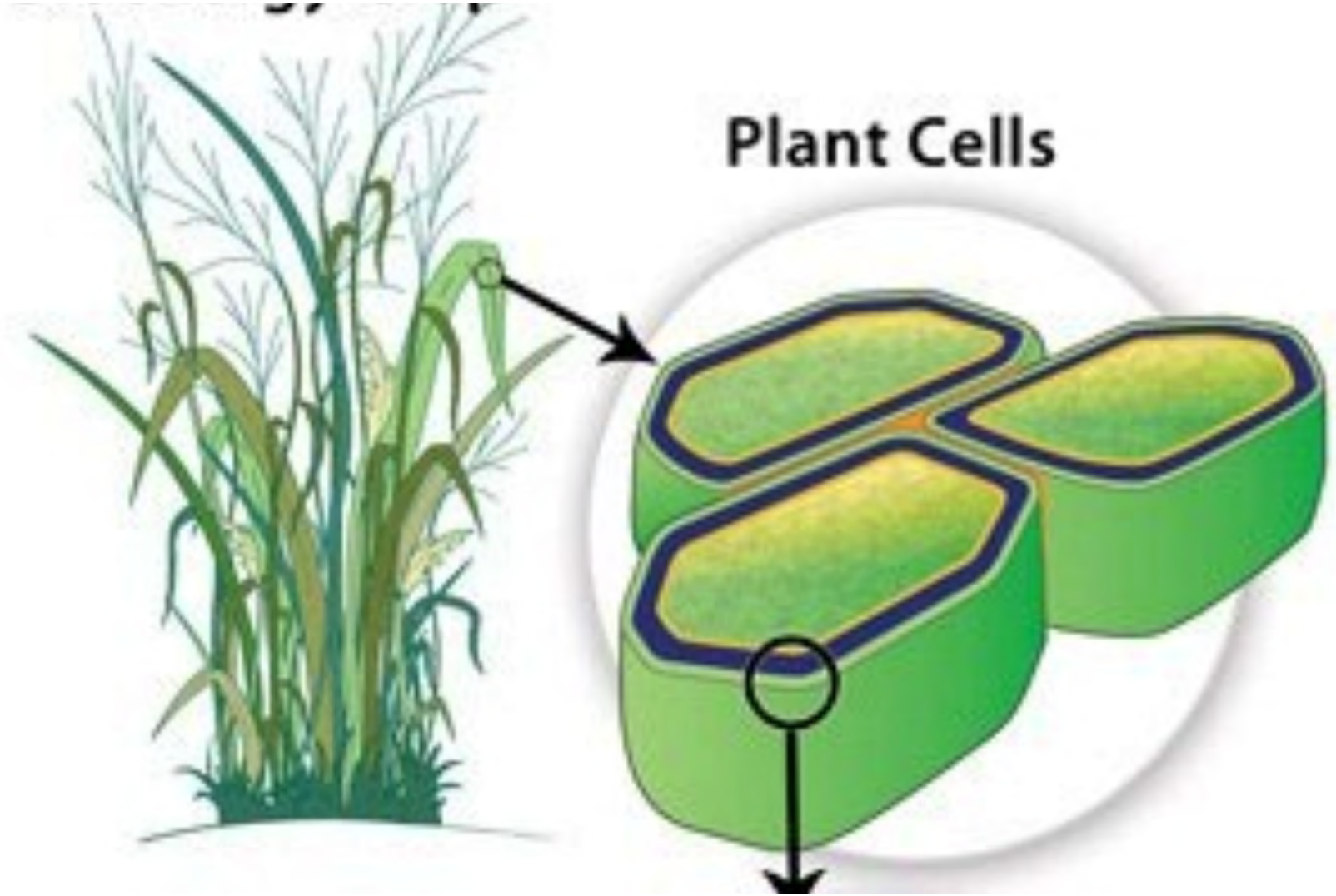
核心技術

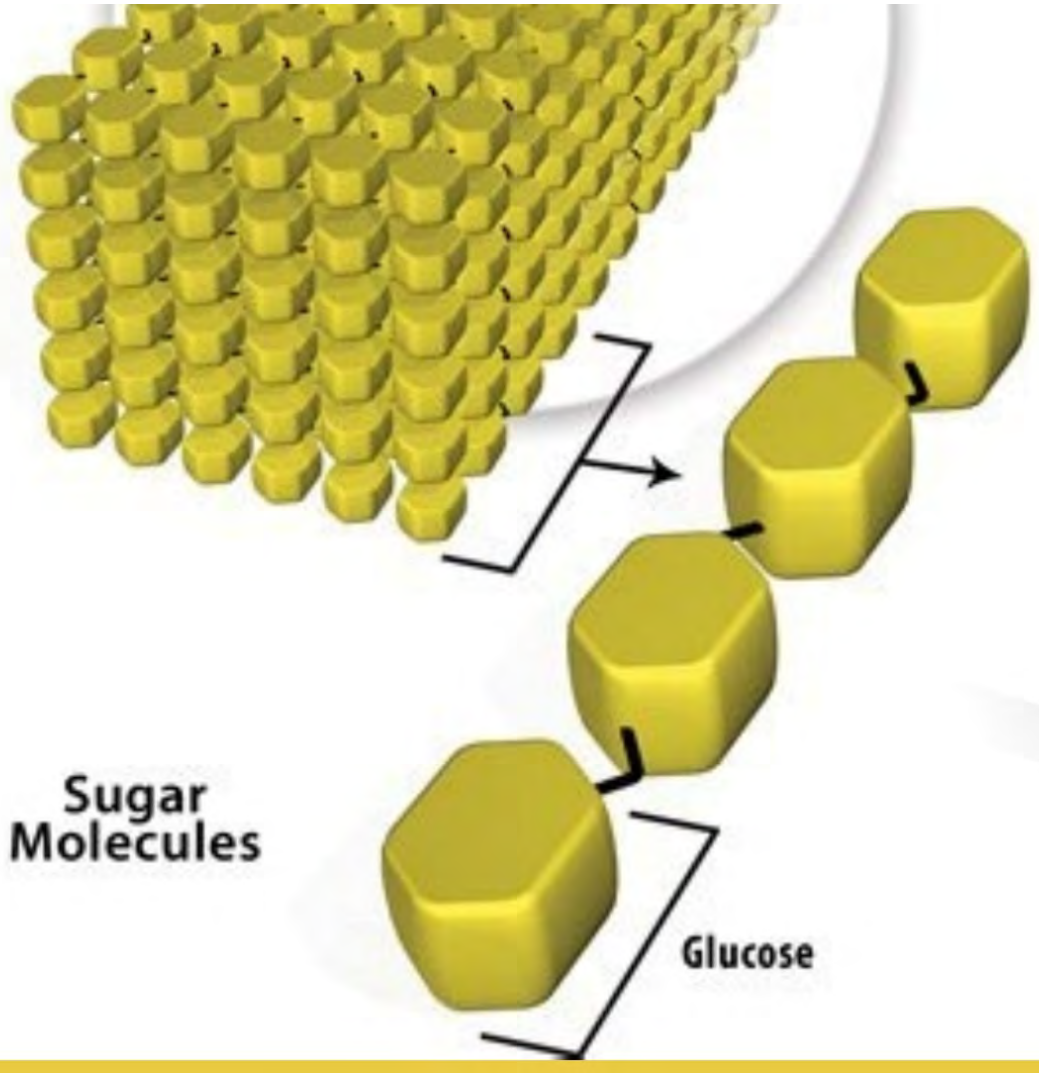
醋酸纖維素的結構


Bioenergy Crop
Plant Cells
Plant Cell Wall
Lignin
Hemicellulose
Cellulose
Cellulose Microfibril
Sugar Molecules
Glucose

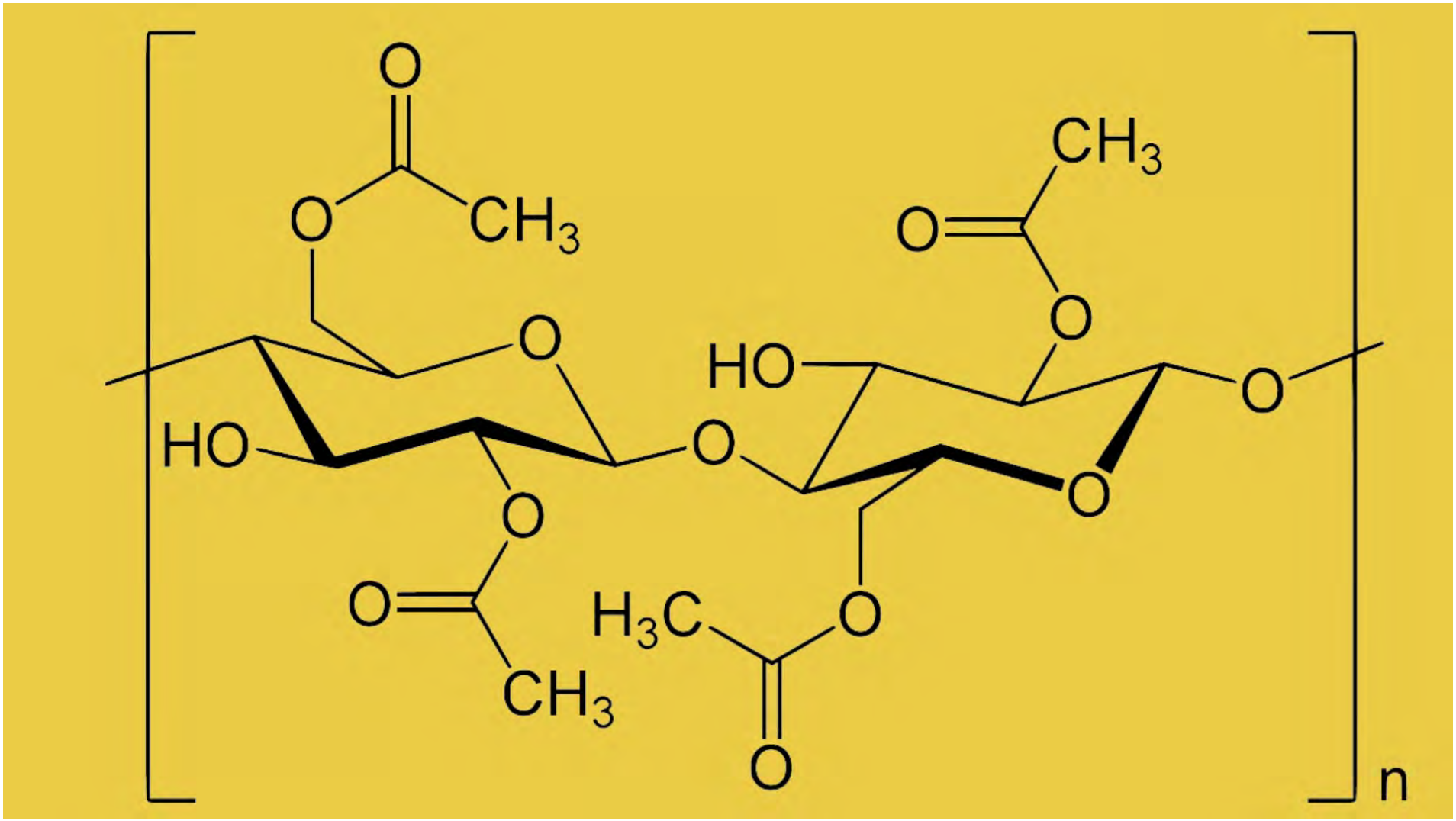


醋酐

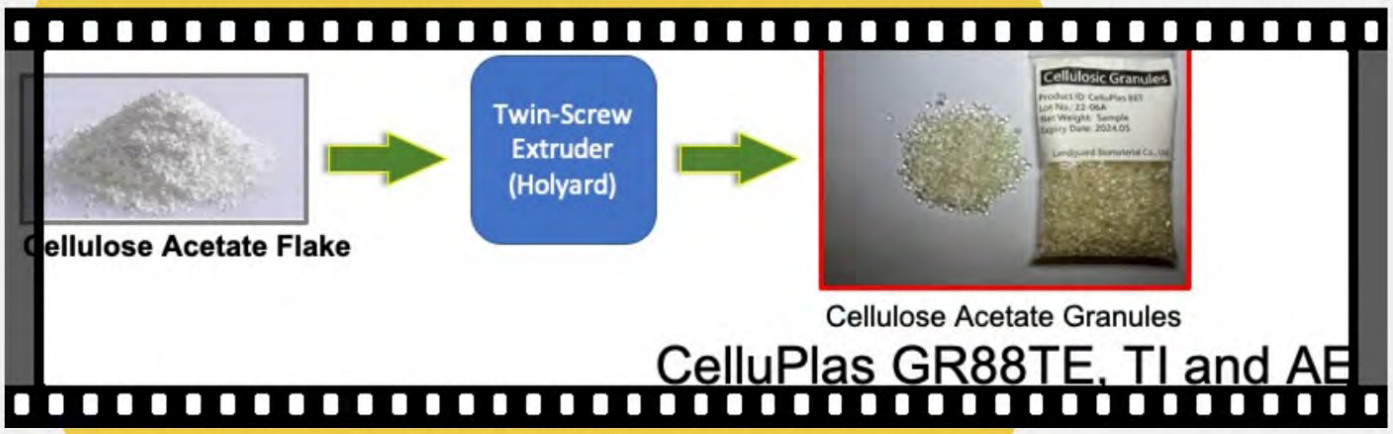

Plant Cells



酯

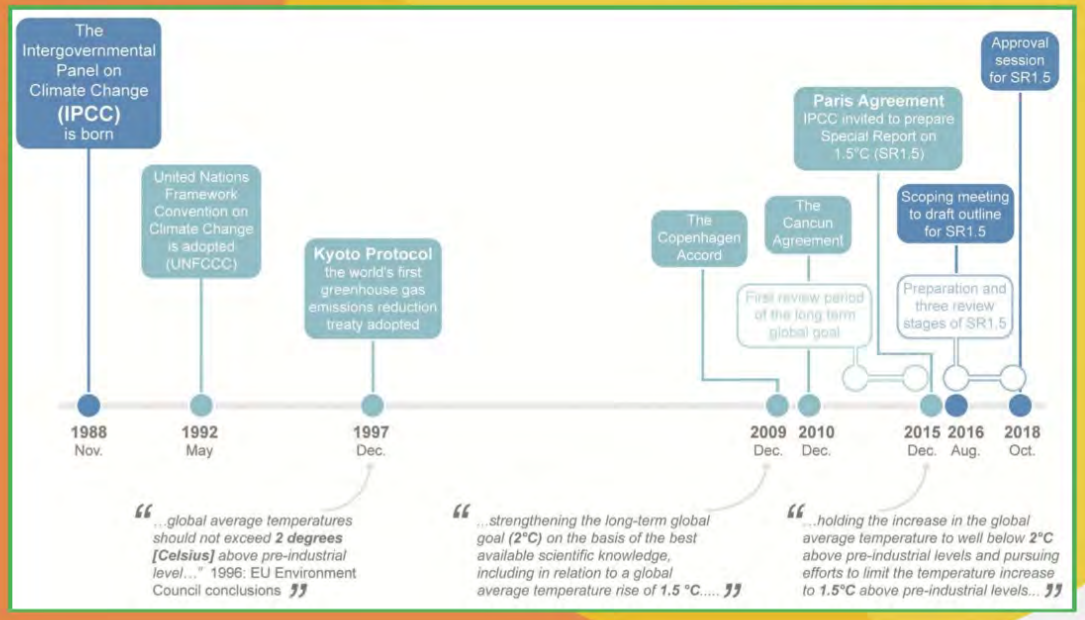

O
O
CH3
CH3
O
O
HO
O
HO
O
O
O
O
O
H3C
O
CH3
O
n

醋酸纖維素熱熔押出


Cellulose Acetate Flake
Twin-Screw Extruder (Holyard)
Cellulosic Granules
Cellulose Acetate Granules
CelluPlas GR88TE, TI and AE


全球氣候變遷與因應
從攝氏2.0度到攝氏1.5度
國際公約
政策法令
執行準則
產業衝擊

聯合國政府間氣候變遷專門委員會（IPCC）
聯合國氣候變化綱要公約（UNFCCC）

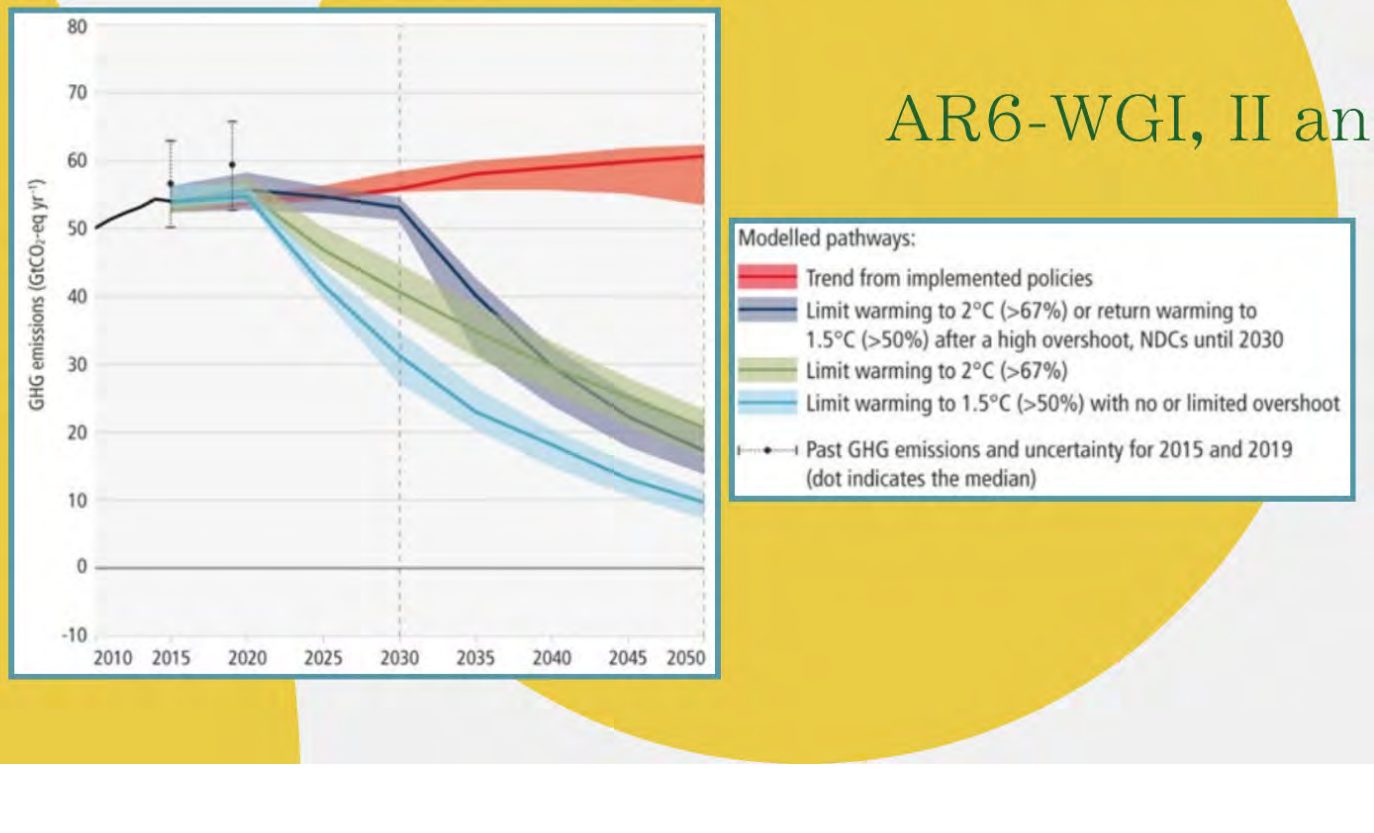


IPCC報告
AR6

UNFCCC
COP26

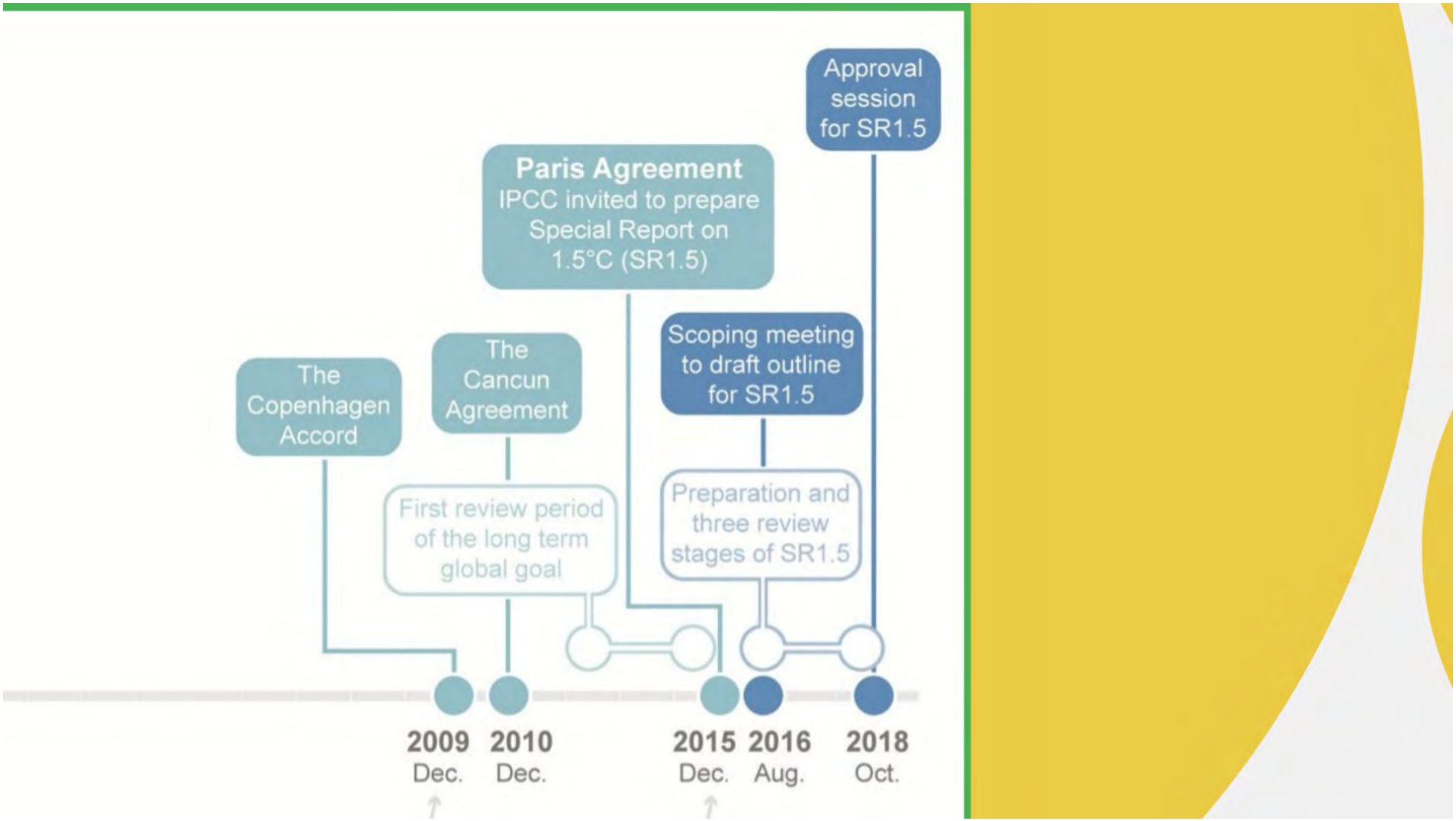
Climate Change 2022

AR6-WGI, II and III



Glasgow Climate Pact

歡迎並導入IPCC AR6報告，並調整因應氣候變遷的目標


Approval session for SR1.5
Paris Agreement
IPCC invited to prepare Special Report on 1.5°C (SR1.5)
Scoping meeting to draft outline for SR1.5
The Copenhagen Accord
The Cancun Agreement
First review period of the long term global goal
Preparation and three review stages of SR1.5
2009 Dec.
2010 Dec.
2015 Dec.
2016 Aug.
2018 Oct.

European Green Deal

Target:

-40% to -55%

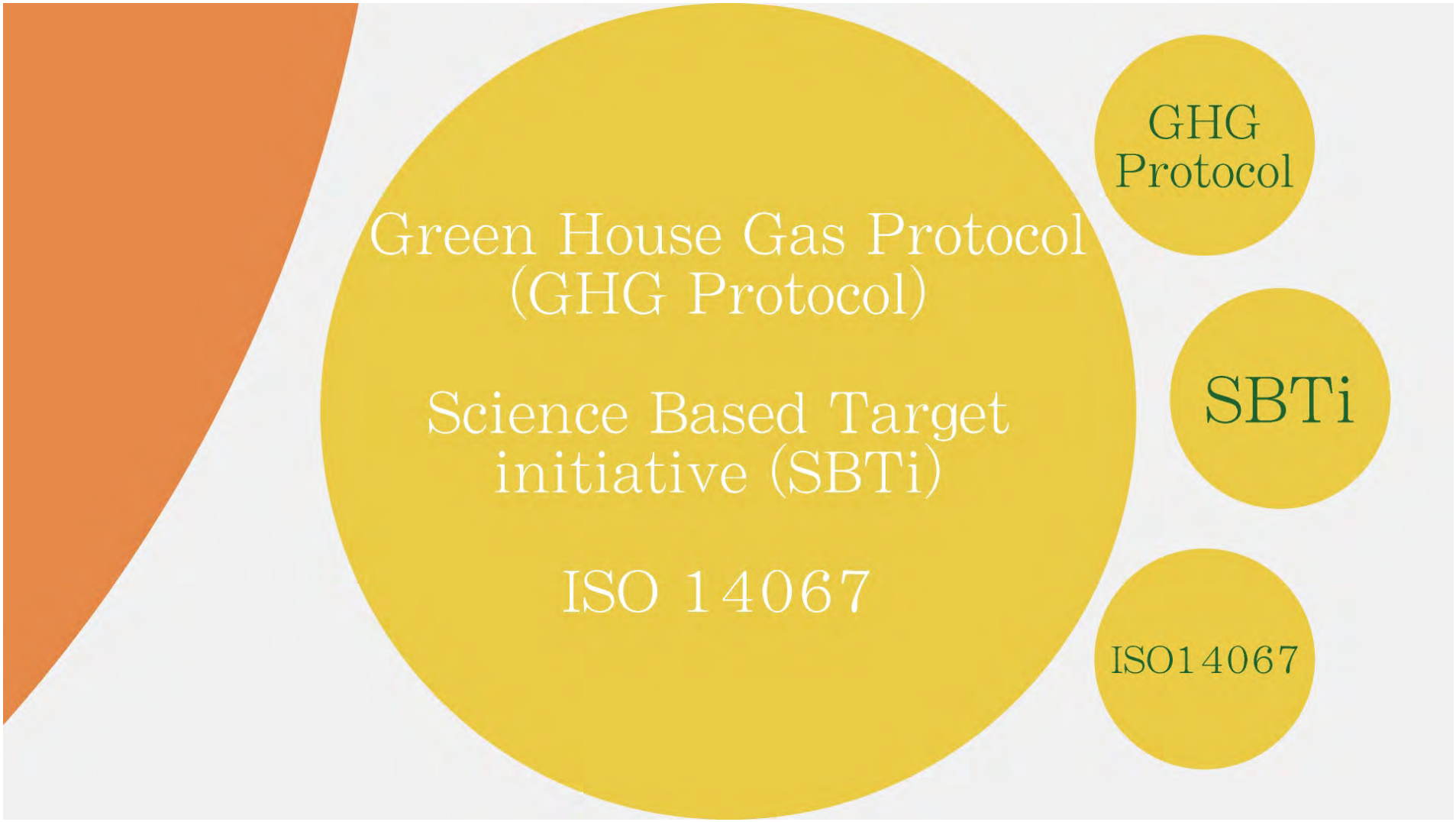
Fit for 55


Climate Social Fund
Emissions trading for road transport and buildings
Carbon Border Adjustment Mechanism
EU Emissions Trading System – for power, industry, maritime & aviation
Land Use, Land Use Change, and Forestry Regulation
Energy Taxation Directive
EU Forest Strategy
2030 CLIMATE TARGETS
Energy Efficiency Directive
Effort Sharing Regulation
Renewable Energy Directive
Alternative Fuels Infrastructure Regulation
CO_2 emissions standards for cars and vans
FuelEU Maritime Initiative
ReFuelEU Aviation Initiative

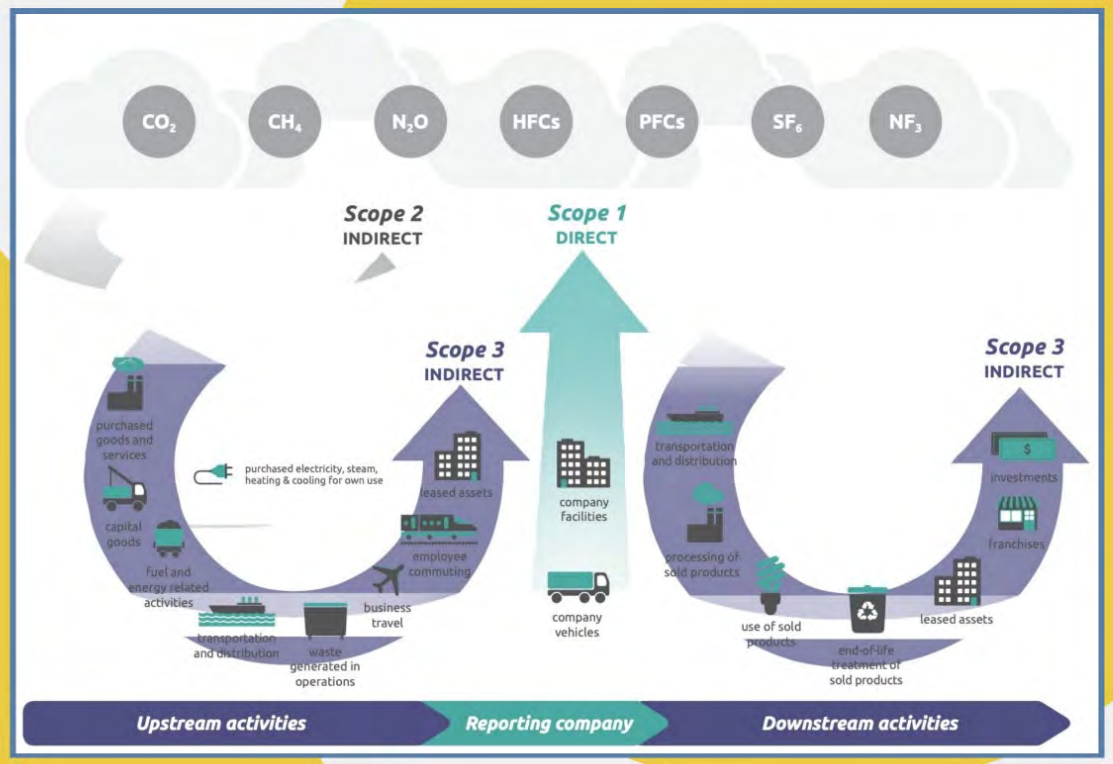
ate Social
Fund

Carbon Border
Adjustment
Mechanism

Emissions
ng System –
ver, industry,


Green House Gas Protocol
(GHG Protocol)
Science Based Target
initiative (SBTi)
ISO 14067
GHG
Protocol
SBTi
ISO14067

Scope 1, 2 and 3



GHG & GWP_{100}

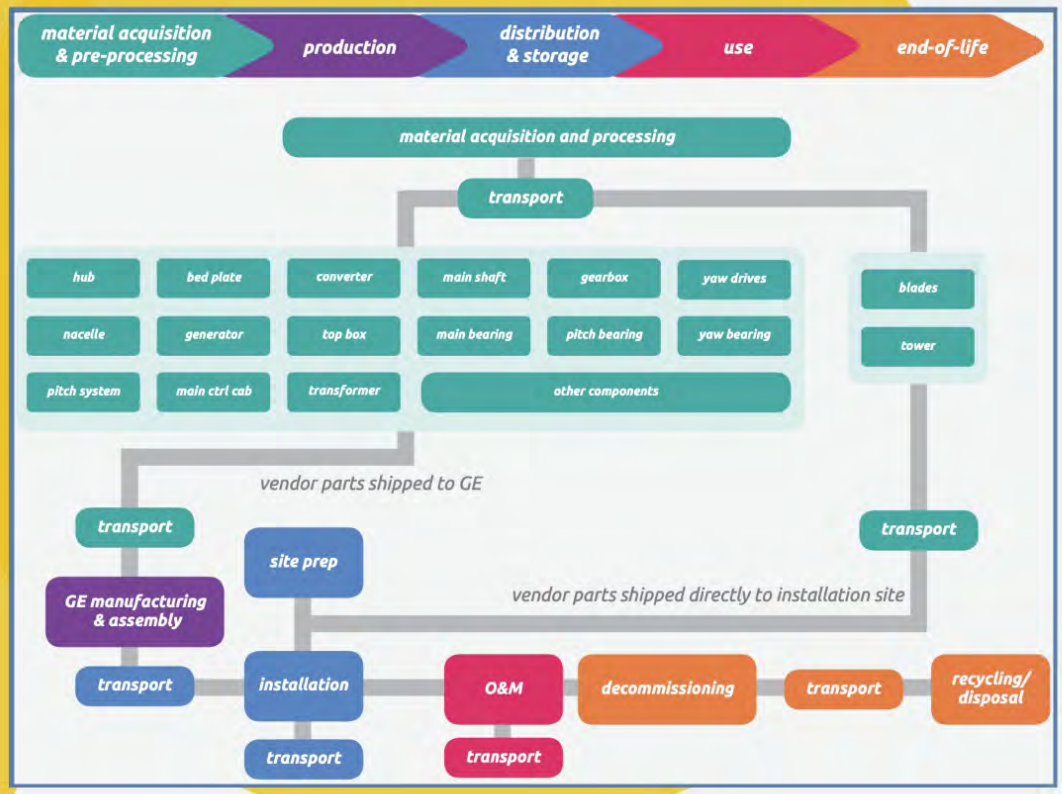
Life Cycle Accessment (LCA)

生物基產品的碳移除

$CO_{2\text{-eq}}$

Industrial designation or common name	Chemical formula	GWP values for 100-year time horizon		
		Second Assessment Report (SAR)	Fourth Assessment Report (AR4)	Fifth Assessment Report (AR5)
Carbon dioxide	CO_2	1	1	1
Methane	CH_4	21	25	28
Nitrous oxide	N_2O	310	298	265

From Cradle to Grave



Scope 3

11. Calculating Inventory Results

- Companies shall apply a 100-year GWP factor to GHG emissions and removals data to calculate the inventory results in units of CO_2 equivalent (CO_2e)
- Companies shall report the source and date of the GWP factors used
- Companies shall quantify and report the following:
  - Total inventory results in CO_2e per unit of analysis, which includes all emissions and removals included in the boundary from biogenic sources, non-biogenic sources, and land-use change impacts
  - Percentage of total inventory results by life cycle stage
  - Biogenic and non-biogenic emissions and removals separately when applicable
  - Land-use change impacts separately when applicable
  - Cradle-to-gate and gate-to-gate inventory results separately or a clear statement that confidentiality is a limitation to providing this information
- Companies shall not include the following when quantifying inventory results: weighting factors for delayed emissions; offsets; and avoided emissions
- Companies shall report the amount of carbon contained in the product or its components that is not released to the atmosphere during waste treatment, if applicable
- For cradle-to-gate inventories, companies shall report the amount of carbon contained in the intermediate product

$$kg\ CO_2e = kg\ Biogenic\ Carbon \times (44/12) \times GWP_{[kg\ CO_2e/kg\ GHG]}$$

$$\frac{Total\ CO_2e}{unit\ of\ analysis} = \frac{CO_2e\ Emissions\ (Biogenic)}{reference\ flow} - \frac{CO_2e\ Removals\ (Biogenic)}{reference\ flow} + \frac{CO_2e\ Emissions\ (Non\text{-}Biogenic)}{reference\ flow} - \frac{CO_2e\ Removals\ (Non\text{-}Biogenic)}{reference\ flow} + \frac{CO_2e\ Land\ Use\ Change\ Impacts}{reference\ flow}$$

Companies shall apply a 100-year GWP factor to GHG emissions and removals data to calculate the inventory results in units of CO_2 equivalent (CO_2e)
Companies shall report the source and date of the GWP factors used
Companies shall quantify and report the following:

- Total inventory results in CO_2e per unit of analysis, which includes all emissions and removals included in the boundary from biogenic sources, non-biogenic sources, and land-use change impacts
- Percentage of total inventory results by life cycle stage
- Biogenic and non-biogenic emissions and removals separately when applicable
- Land-use change impacts separately when applicable
- Cradle-to-gate and gate-to-gate inventory results separately or a clear statement that confidentiality is a limitation to providing this information

Companies shall not include the following when quantifying inventory results: weighting factors for delayed emissions; offsets; and avoided emissions
Companies shall report the amount of carbon contained in the product or its

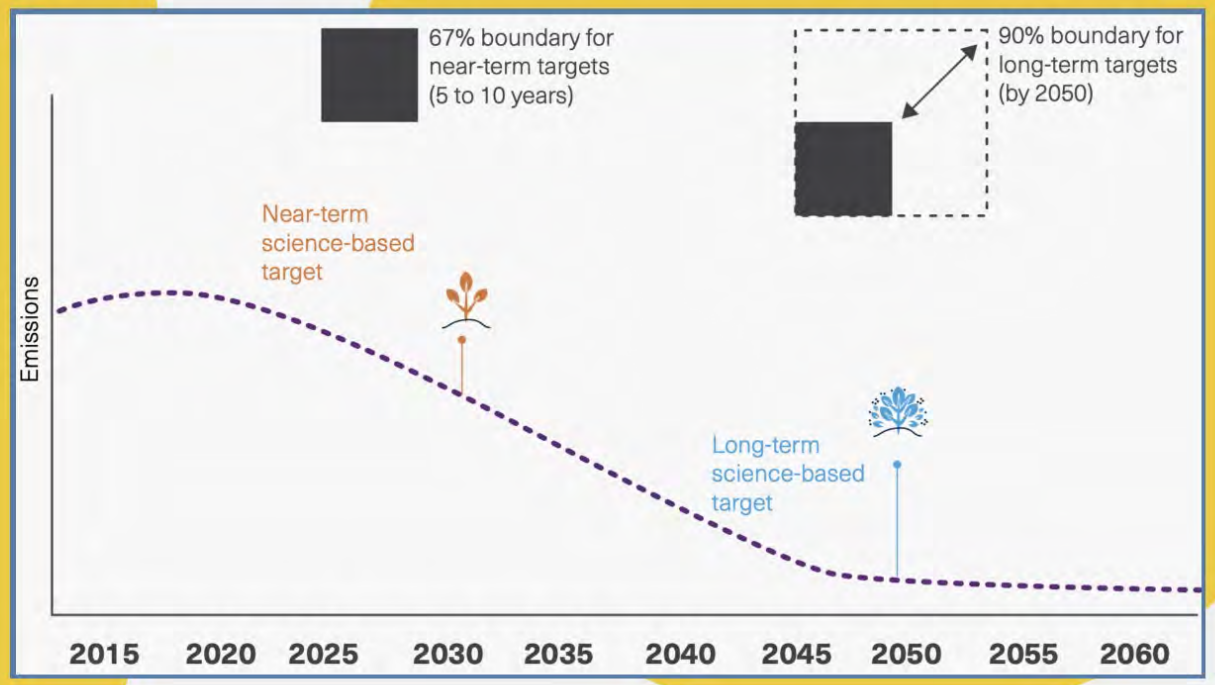
treatment,

t of carbon

$$kg\ CO_2e = kg\ Biogenic\ Carbon \times (44/12) \times GWP \quad [kg\ CO_2e/kg\ GHG]$$

$$\frac{Total\ CO_2e}{unit\ of\ analysis} = \frac{CO_2e\ Emissions\ (Biogenic)}{reference\ flow} - \frac{CO_2e\ Removals\ (Biogenic)}{reference\ flow} + \frac{CO_2e\ Emissions\ (Non\text{-}Biogenic)}{reference\ flow} - \frac{CO_2e\ Removals\ (Non\text{-}Biogenic)}{reference\ flow} + \frac{CO_2e\ Land\ Use\ Change\ Impacts}{reference\ flow}$$


SELECT A BASE YEAR
CALCULATE YOUR COMPANY'S EMISSIONS
SET TARGET BOUNDARIES
CHOOSE A TARGET YEAR
CALCULATE TARGETS


67% boundary for near-term targets (5 to 10 years)
90% boundary for long-term targets (by 2050)
Near-term science-based target
Long-term science-based target
Emissions
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060

生物基產品的碳移除

Net Zero Guide

5.2.2 Greenhouse Gas Protocol Guidance on Carbon Removals and Land Use

In parallel and in coordination, The Greenhouse Gas Protocol is undertaking a process to develop new guidance on carbon removals and land use. This project is due for completion at the end of 2022. The GHG Protocol guidance will provide information to companies on how to account for and report the following activities in their greenhouse gas inventories:

- Land use/management and land use change
- Carbon removals and storage
- Bioenergy and other biogenic products
- Related topics

C11 — Bioenergy accounting: CO_2 emissions from the combustion, processing and distribution phase of bioenergy and the land use emissions and removals[15] associated with bioenergy feedstocks, shall

13 Where a company's scope 1 or 2 emissions are deemed immaterial (i.e., under 5% of total combined scope 1 and 2 emissions), companies may set their SBT solely on the scope (either scope 1 or scope 2) that covers more than 95% of the total scope 1 and 2 emissions. The company must continue to report on both scopes and adjust their targets as needed, in accordance with the GHG Protocol's principle of completeness and as per C32 and C33.

14 For a definition of the minimum boundaries of scope 3 categories and emissions sources that fall outside the minimum boundaries, see Table 5.4 (page 36) of the Corporate Value Chain (Scope 3) Accounting and Reporting Standard.

15 The positive impact of exceeding zero emissions due to biogenic removals shall not be accounted for in a company's target formulation or as progress towards SBTs. In addition, removals that are not directly associated with bioenergy feedstock production are not accepted to count as progress towards SBTs or to net emissions in a company's GHG inventory.

orate Net-Zero Standard | Version 1.0 | October 2021

be reported alongside a company's GHG inventory. Furthermore, CO_2 emissions from the combustion, processing and distribution phase of bioenergy and the land use emissions and removals associated with bioenergy feedstocks shall be included in the target boundary when setting a science-based target (in scopes 1, 2, and/or 3, as relevant) and when reporting progress against that target.

R5 — Bioenergy data reporting: The SBTi recommends that companies report direct biogenic CO_2 emissions and removals from bioenergy separately. Emissions and removals of CO_2 associated with bioenergy shall be reported as net emissions according to C11, at a minimum, but companies are encouraged to also report gross emissions and gross removals from bioenergy feedstocks.

Net

5.2.2 Greenhouse Gas Protocol Guidance on Carbon Removals and Land Use

In parallel and in coordination, The Greenhouse Gas Protocol is undertaking a process to develop new guidance on carbon removals and land use. This project is due for completion at the end of 2022. The GHG Protocol guidance will provide information to companies on how to account for and report the following activities in their greenhouse gas inventories:

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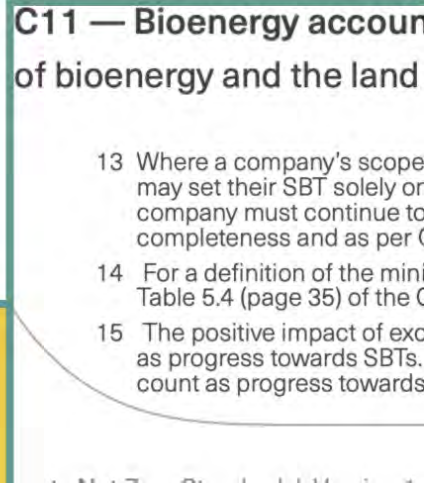
- Carbon removals and storage
- Bioenergy and other biogenic products
- Related topics



C11 — Bioenergy accoun
of bioenergy and the land

13 Where a company's scope
may set their SBT solely or
company must continue to
completeness and as per (

14 For a definition of the mini
Table 5.4 (page 35) of the (

15 The positive impact of exc
as progress towards SBTs.
count as progress towards

C11 — Bioenergy accounting: CO_2 emissions from the combustion, processing and distribution phase of bioenergy and the land use emissions and removals[15] associated with bioenergy feedstocks, shall

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orate Net-Zero Standard | Version 1.0 | October 2021

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ıermore, CO_2 emissions from the combustion,
and use emissions and removals associated
: boundary when setting a science-based
ɔorting progress against that target.

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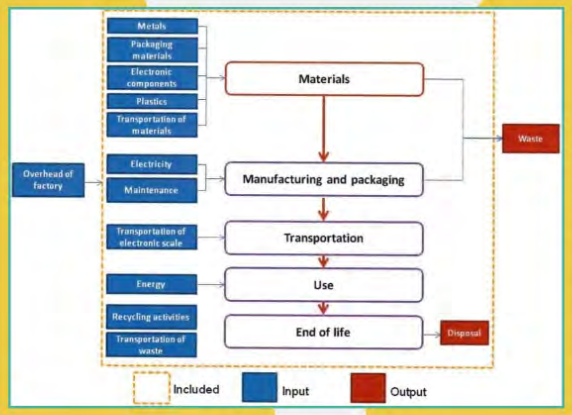
- 碳足跡的量化方法
- 碳足跡研究的步驟指引

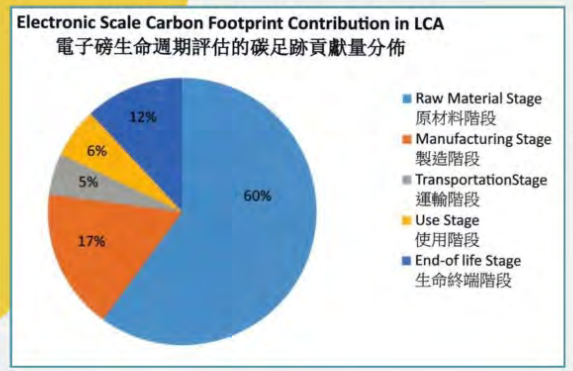
案例研究一

案例研究二

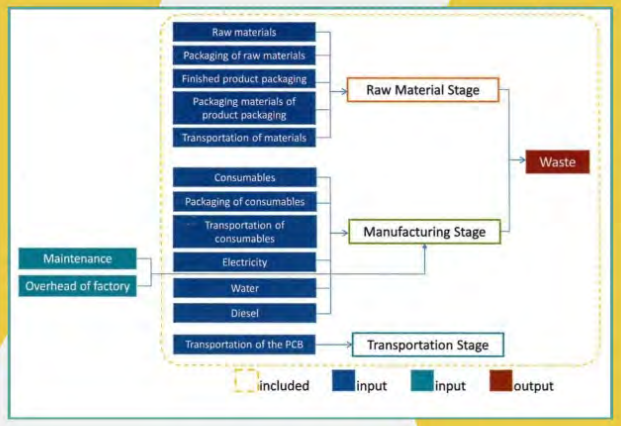
電子磅秤（B2C)



生命週期階段	資料類型	資料內容
原材料階段	初級資料（現場數據）	使用的材料及零部件數量
	二級資料	材料及零部件的排放因子
製造階段	初級資料（現場數據）	製造過程中的用電量
	二級資料	電力的排放因子
運輸階段	初級資料（現場數據）	運輸路線的路程
		使用的運輸工具
	二級資料	運輸路線的排放因子
使用階段	模擬使用情景	使用的資源消耗
	二級資料	使用的資源的排放因子
生命終端階段	模擬情景	運輸路線的路程
		使用的運輸工具
	模擬情景	處置活動的排放因子

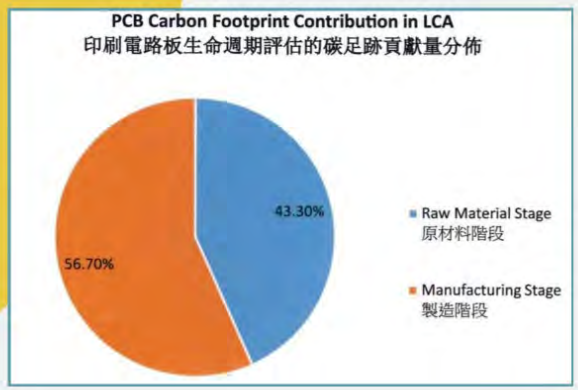


印刷電路板PCB（B2B）

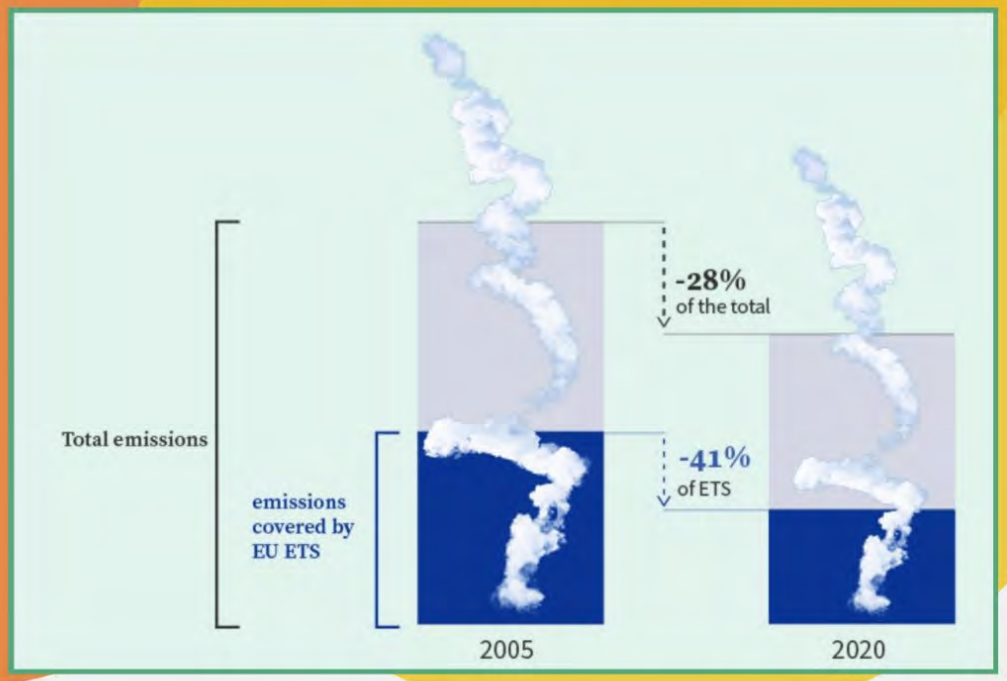


表格5. 案例四印刷電路板(PCB)的數據及數據品質

生命週期階段	資料類型	資料內容
原材料階	初級資料（現場數據）	使用的材料及零部件數量
	二級資料	材料及零部件的排放因子
製造階段	初級資料（現場數據）	製造過程中使用的電力、用水以及產生的廢棄物數量
	二級資料	用電用水的排放因子
運輸階段(參考）	初級資料（現場數據）	使用的運輸工具
	二級資料	運輸路線的排放因子
		運輸路線的路程



ETS 與 CBAM

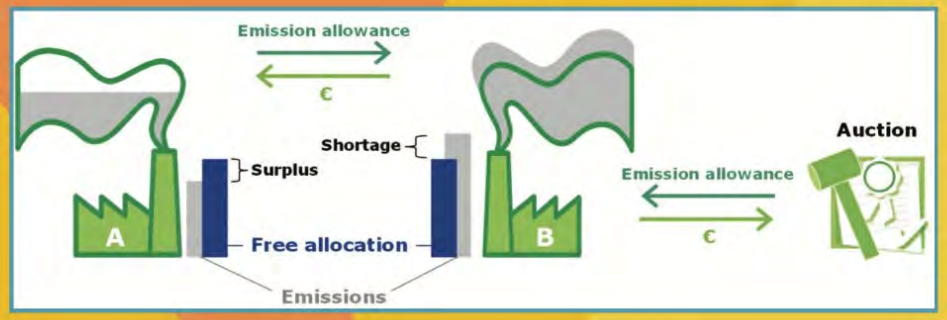


ETS

CBAM

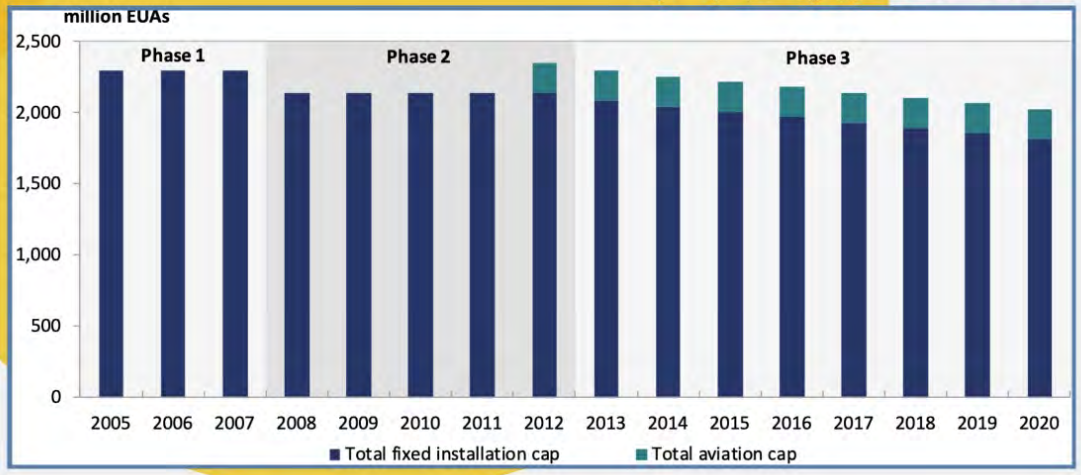
案例分析

Cap and Trade

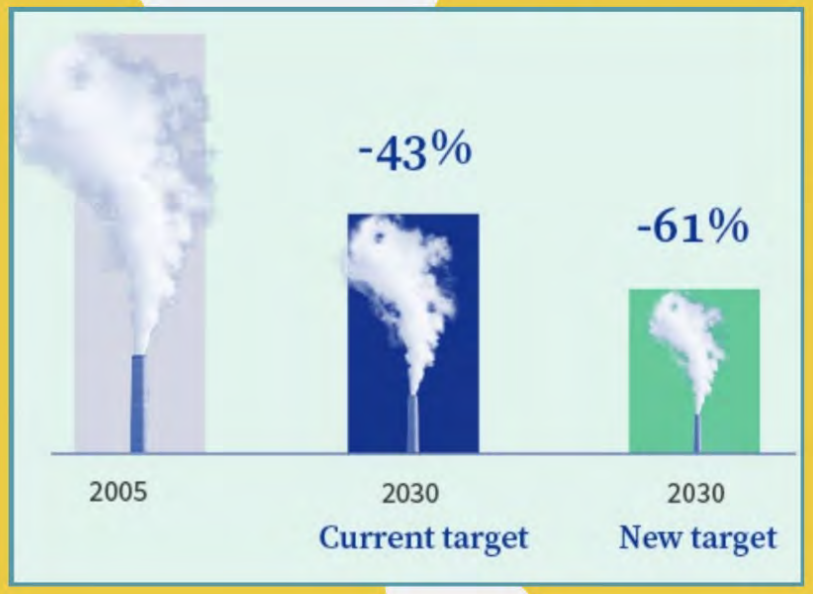


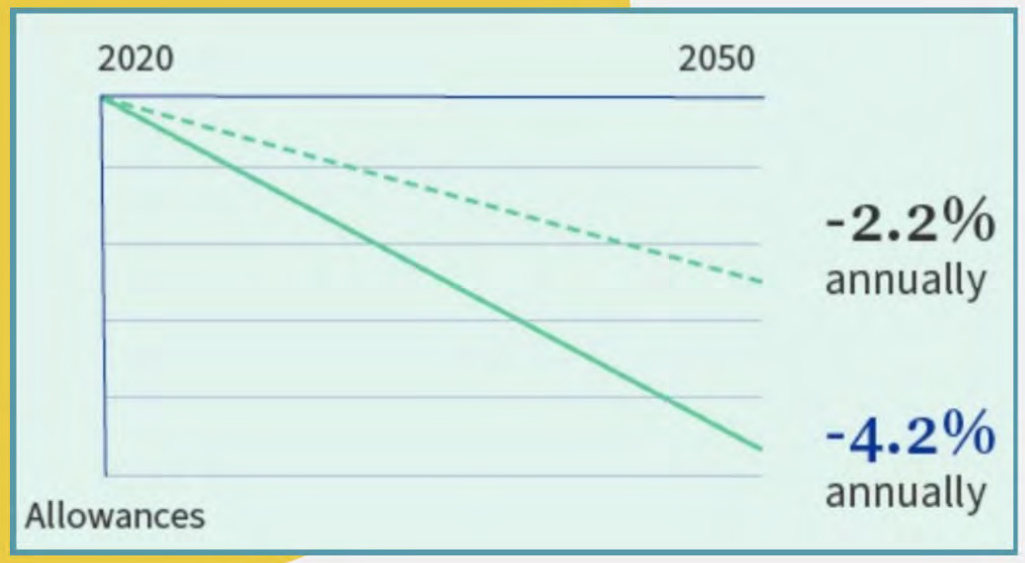
目標更新

每年遞減1.74%

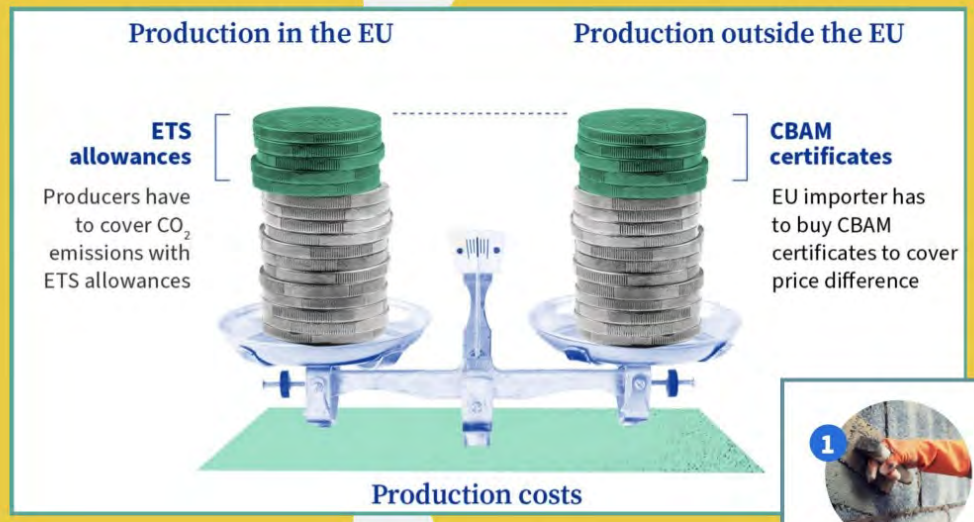


ETS Phase 4


-43%
-61%
2005
2030
Current target
2030
New target


2020
2050
-2.2%
annually
-4.2%
annually
Allowances

Carbon Leakage



2026

以德國鋼鐵業為例

以德國鋼鐵業為例

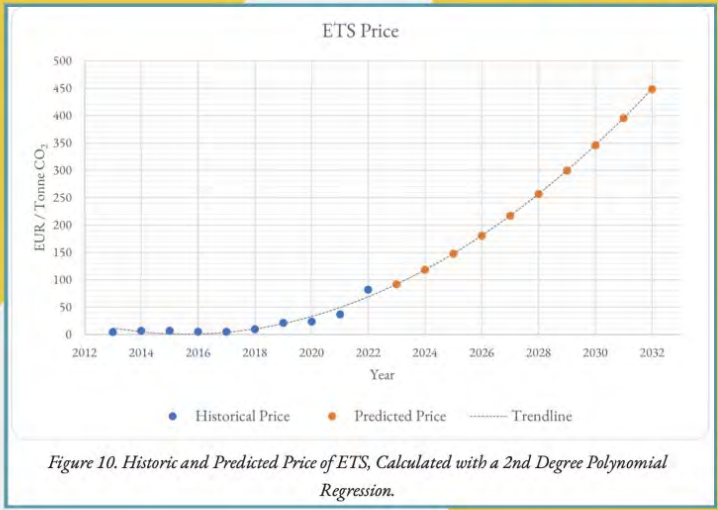


Figure 10. Historic and Predicted Price of ETS, Calculated with a 2nd Degree Polynomial Regression.

以德國鋼鐵業為例

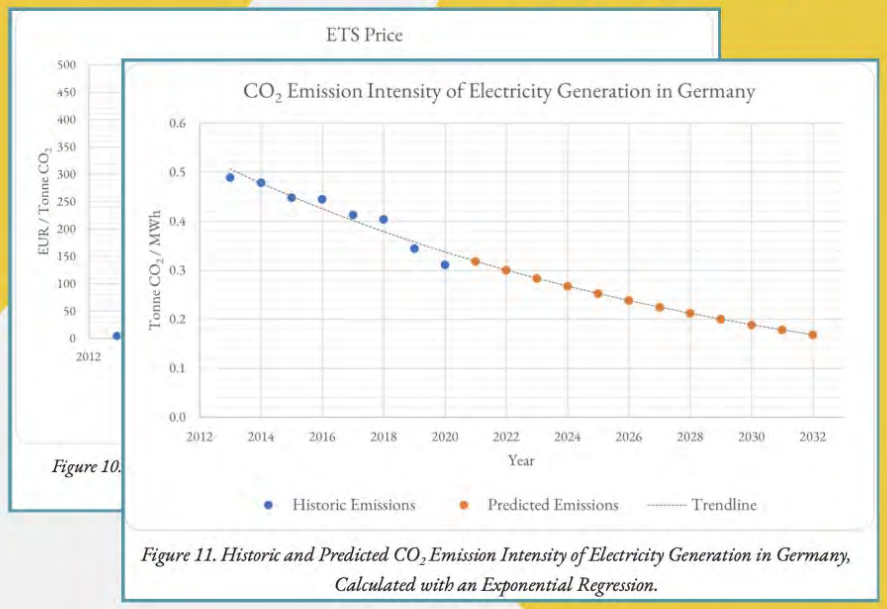


Figure 10.

Figure 11. Historic and Predicted CO_2 Emission Intensity of Electricity Generation in Germany, Calculated with an Exponential Regression.

以德國鋼鐵業為例

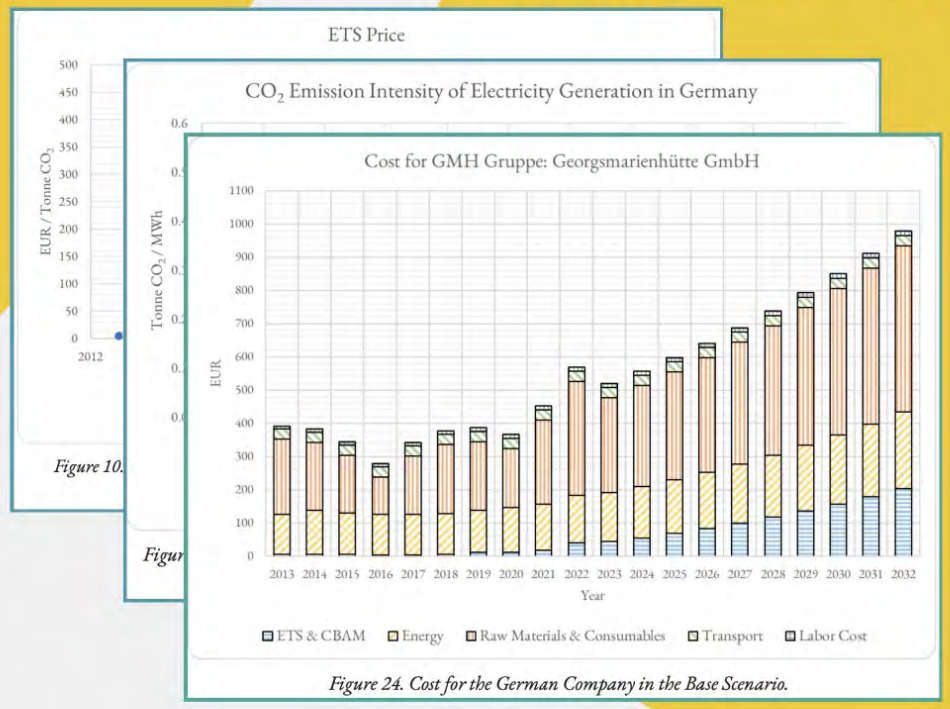


Figure 24. Cost for the German Company in the Base Scenario.

以德國鋼鐵業為例

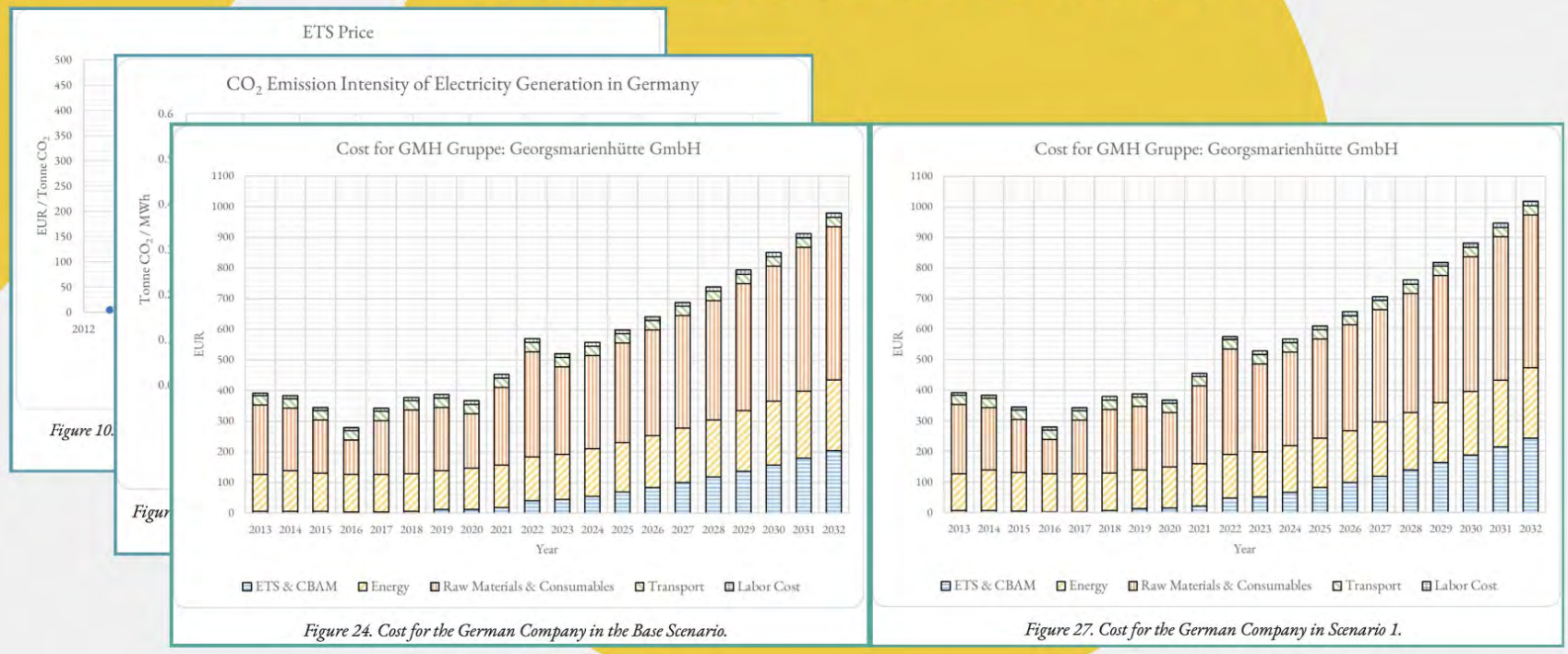


Figure 10.

Figur

Figure 24. Cost for the German Company in the Base Scenario.

Figure 27. Cost for the German Company in Scenario 1.

以德國鋼鐵業為例

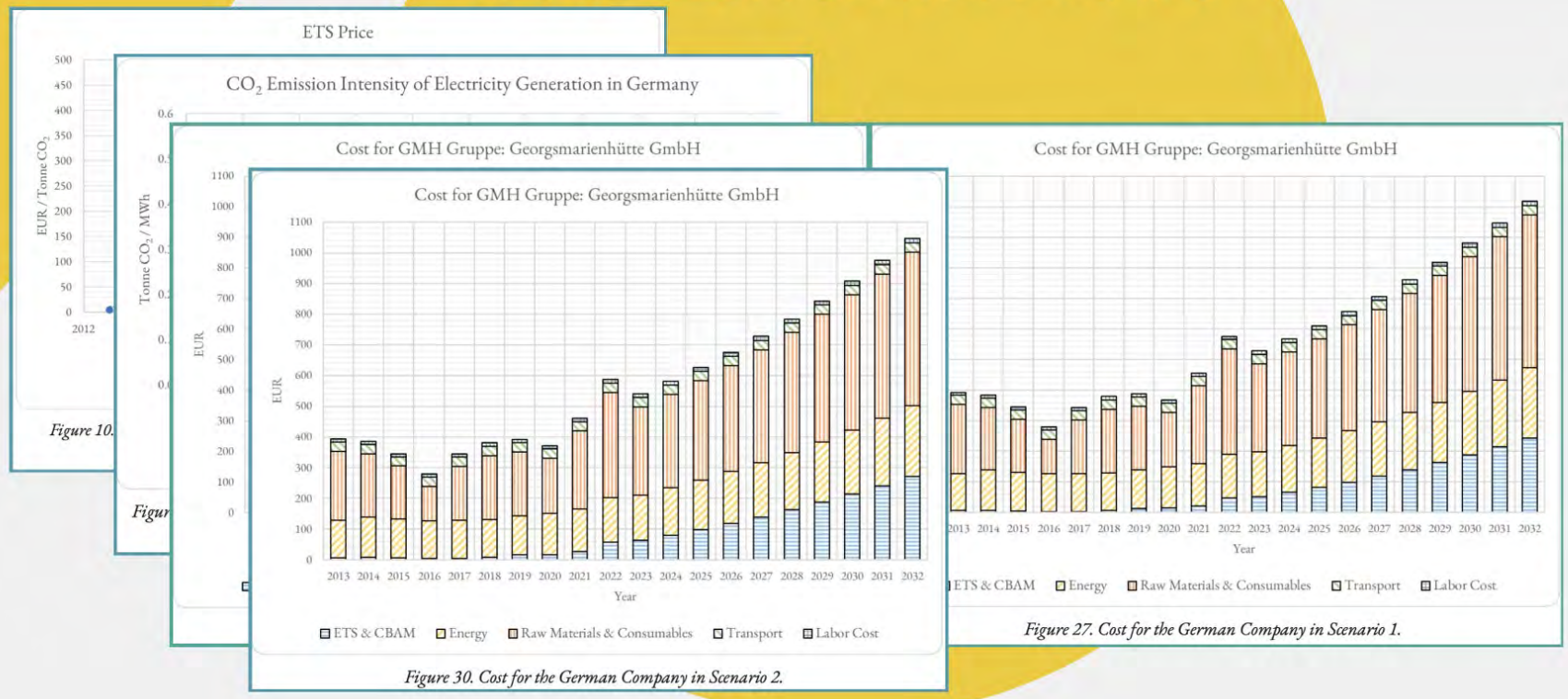


Figure 10.

Figur

Figure 30. Cost for the German Company in Scenario 2.

Figure 27. Cost for the German Company in Scenario 1.

以德國鋼鐵業為例

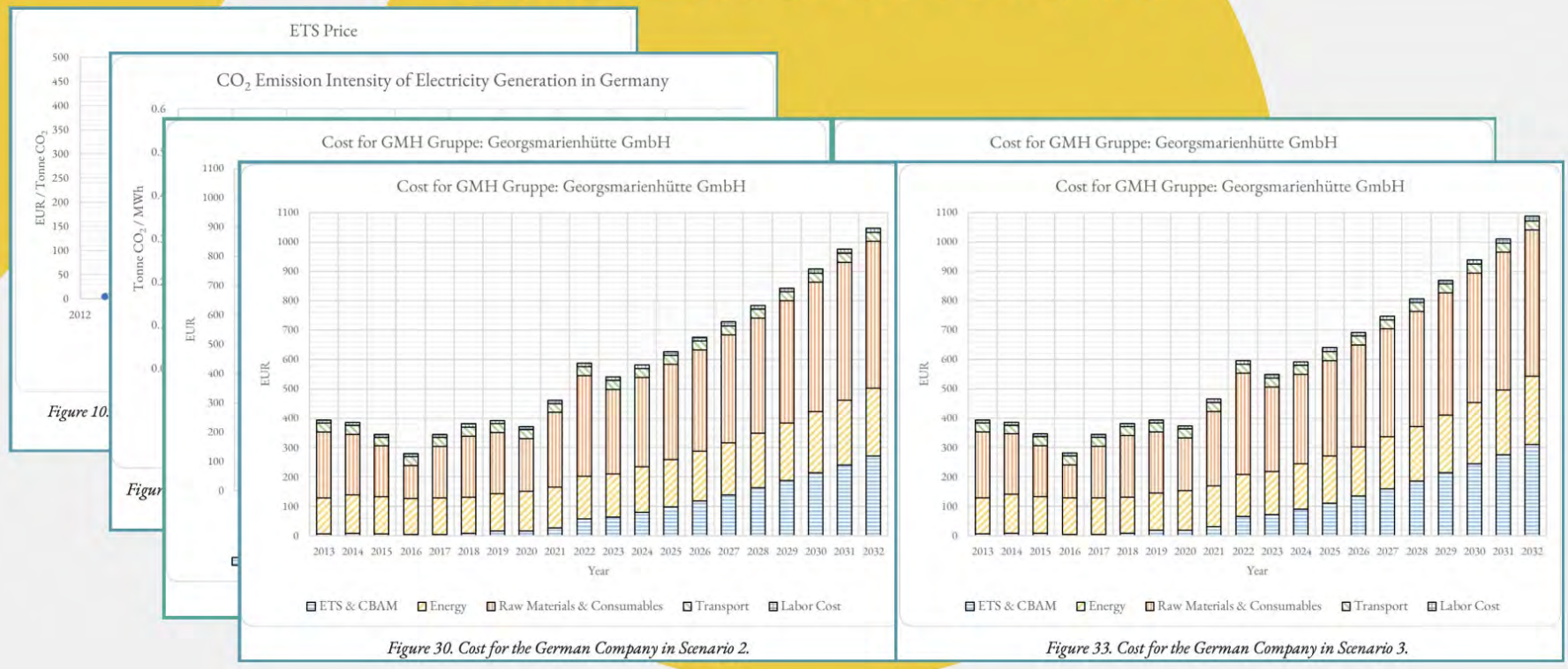


Figure 30. Cost for the German Company in Scenario 2.

Figure 33. Cost for the German Company in Scenario 3.

TPS100的碳足跡試算

From Cradle to Gate

應用二

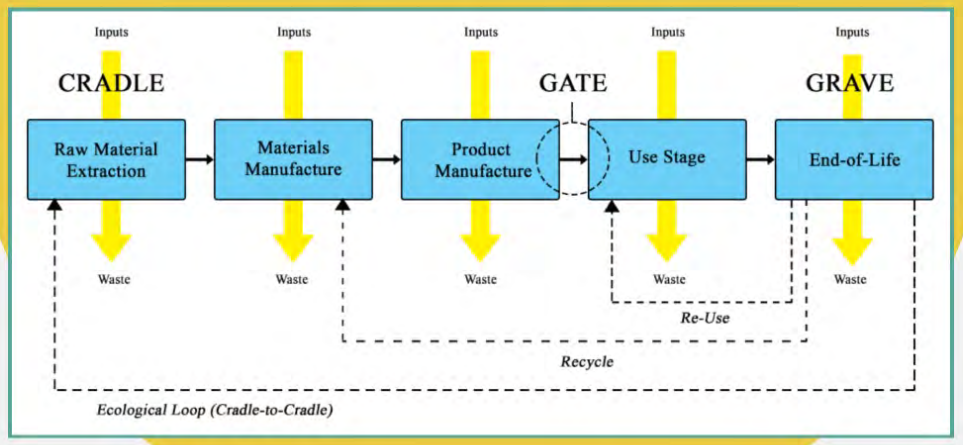
應用一

溫室氣體清冊 (GHG Inventory)

原物料

碳移除

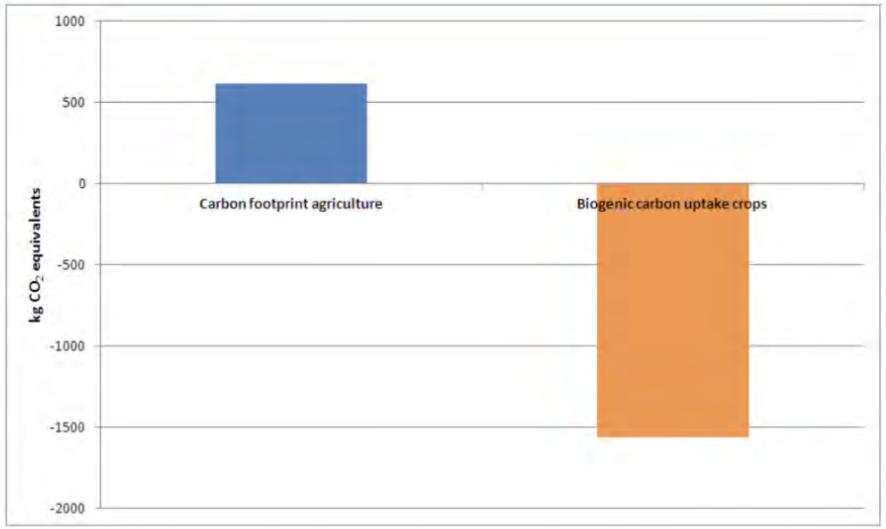
碳排放



100% Biogenic Carbon

成分	含量(wt%)
樹薯澱粉	80-85
生質增塑劑	15-18
生質助劑	1.2-1.8

歐洲澱粉工業協會資料



生產 1 公噸乾燥澱粉的碳排放和碳吸收(摘自 An et al., 2012, Figure 5 原圖)

泰國樹薯澱粉製造商資料

	澱粉種植	澱粉製造	合計
平均碳排放 (kg CO_2 e/ton)	302	292	**594**

根據上述資料，泰國東北部生產每公噸乾燥樹薯澱粉的平均碳排放為 0.594 公噸。

自行計算

	kg $CO_{2\,eq}$/ton TPS100
樹薯澱粉（碳移除）	-850
樹薯澱粉（碳排放）	505
增塑劑	1.6
助劑	NA
混練加工	230
合計	-113.4

與其他聚合物共混

Amyloflex 5050 (TPS100/PBAT共混)

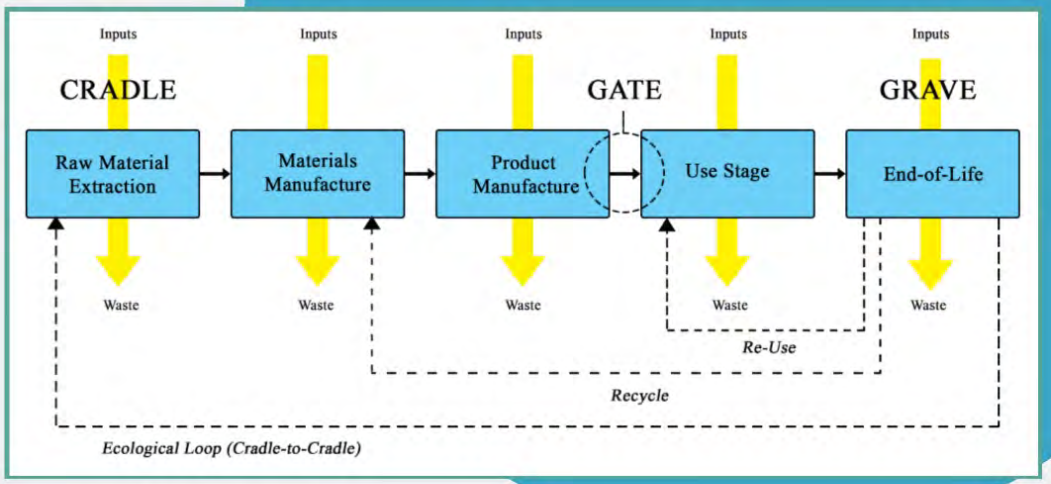
	Amyloflex 5050 (kg $CO_{2\ eq}$)	LDPE (kg $CO_{2\ eq}$)
PBAT	1,150	3,000
TPS100	-67	0
混練加工	230	0
合計	1,313(-56%)	3,000

作為母粒添加

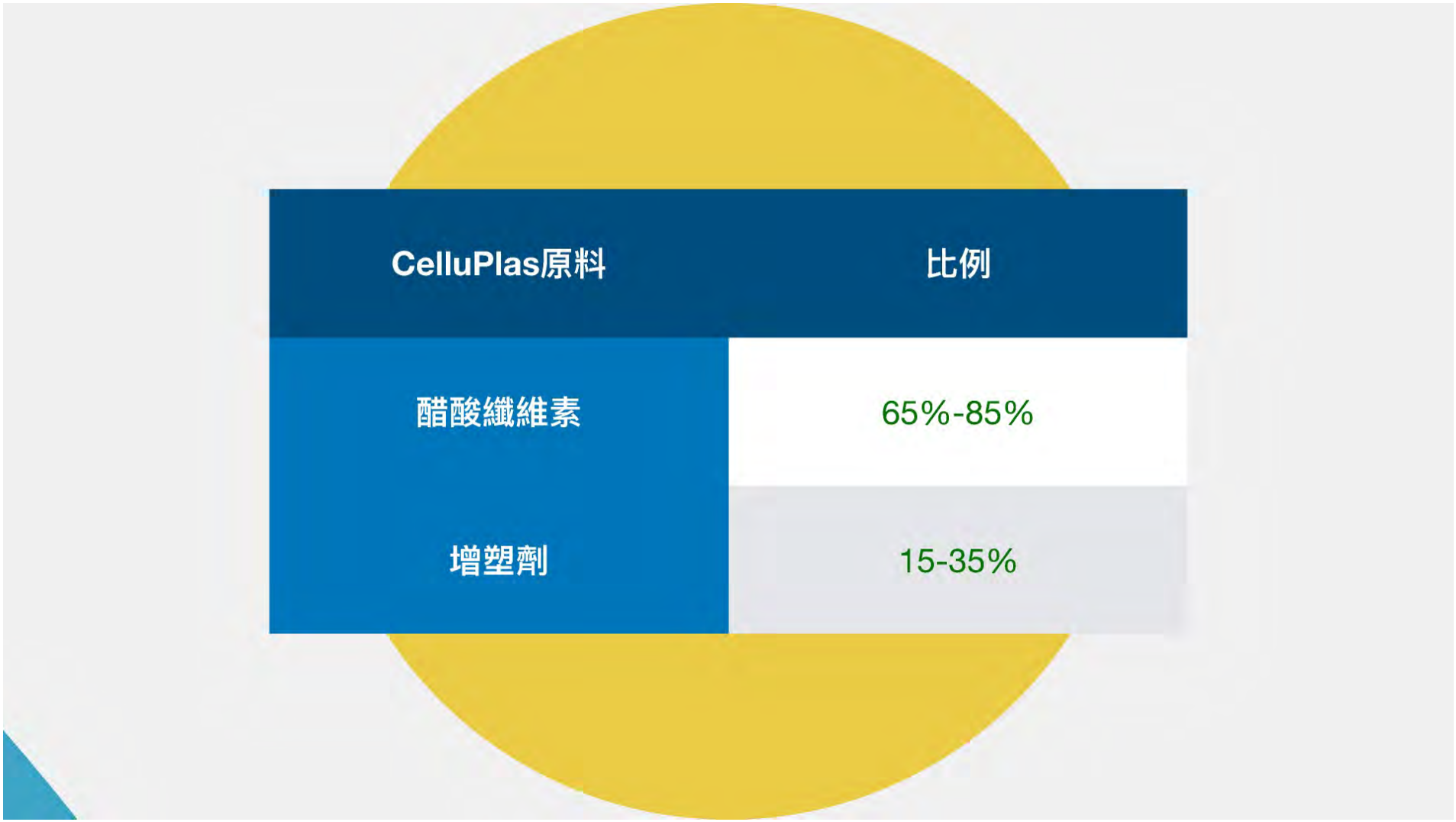
	LDPE (kg CO_2 e/ton)	TPS100-PE (kg CO_2 e/ton)	備註
LDPE	3,000	2,250	
TPS100	0	-28.4	
PE 接枝劑	0	60	供應商無法提供資料，以 PE 的數據，扣除接枝率後 PE 含量作為計算基礎
混練加工	0	230	
合計	3,000	2,512(-16.3%)	

CelluPlas的碳足跡試算

From Cradle to Gate



- 原物料
- 碳移除
- 碳排放
- 溫室氣體清冊
- 應用


CelluPlas原料
比例
醋酸纖維素
65%-85%
增塑劑
15-35%

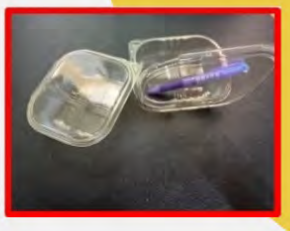
CelluPlas原料	上游原料（ton)	碳移除 (ton CO2 eq/ton)
醋酸纖維素	纖維素	6.2X0.37%=2.3
增塑劑	組成分A	0.028

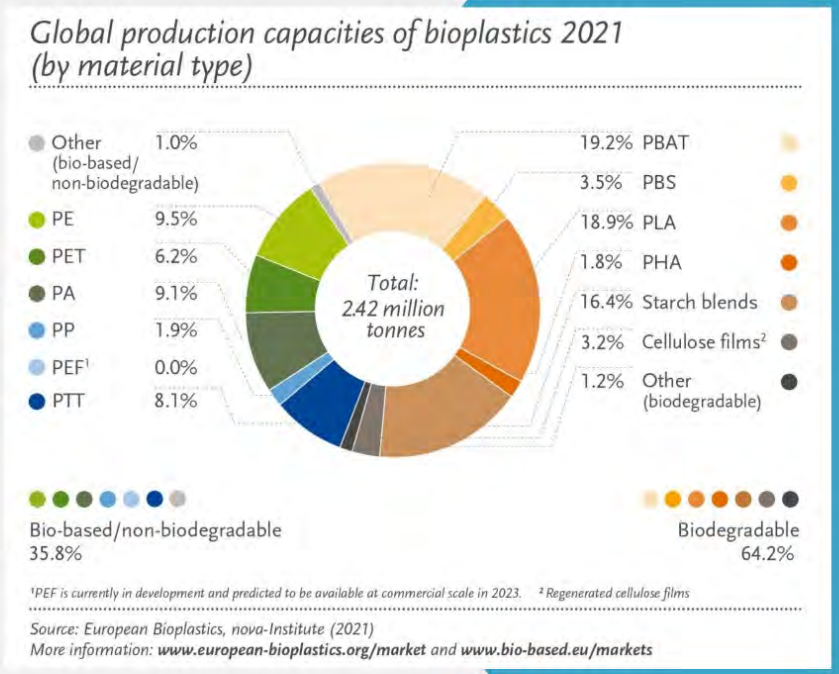
CelluPlas原料	上游原料	碳排放 ton kg CO_2 eq
醋酸纖維素	纖維素	2.2
增塑劑	組成分A	0.15

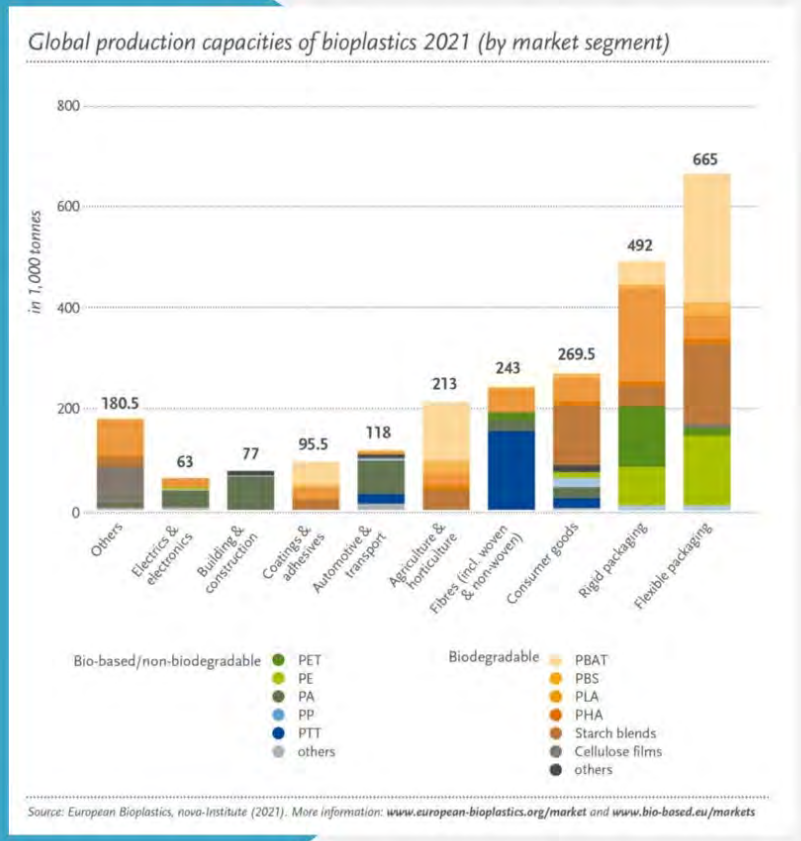
自行計算

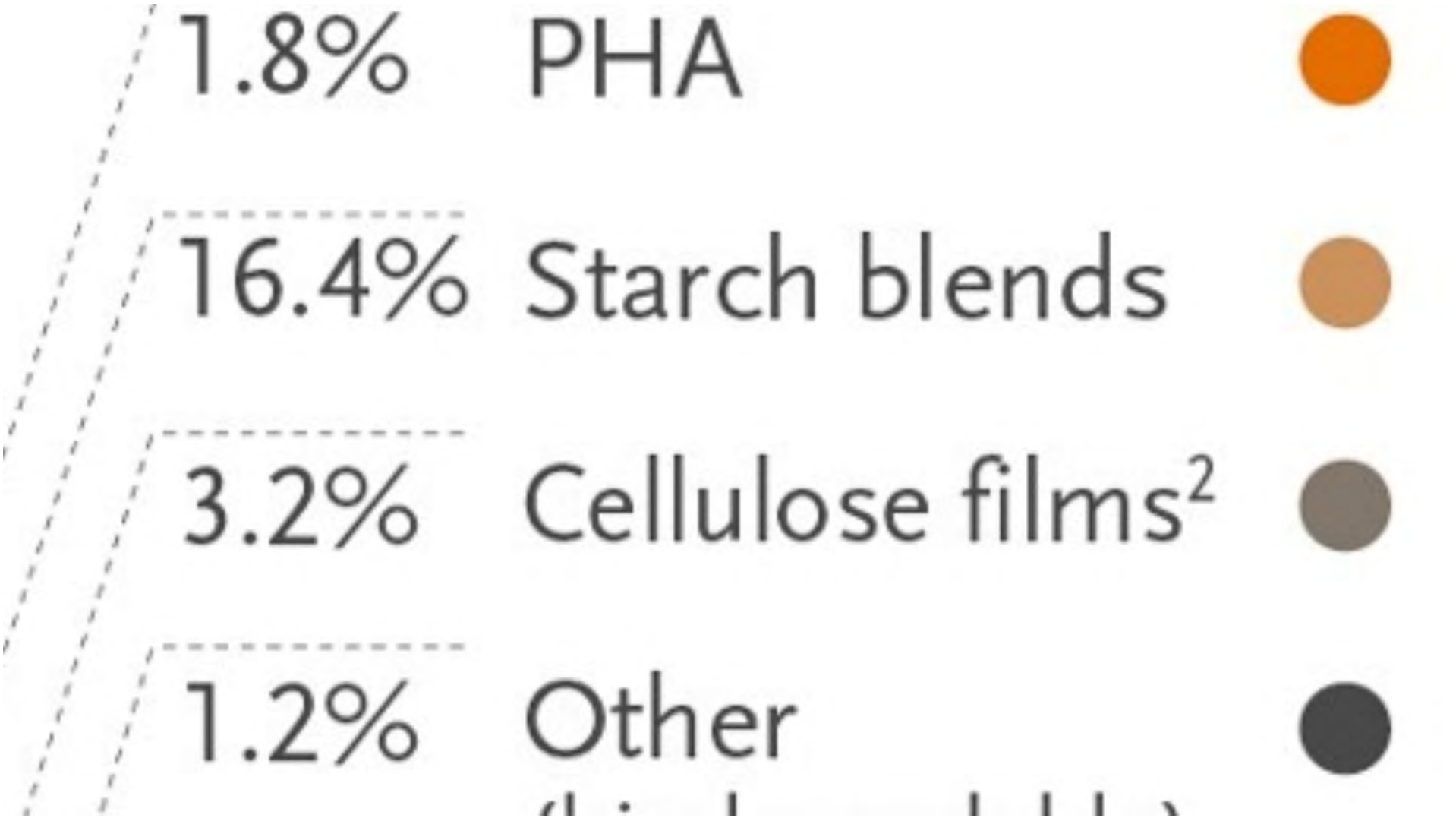
	CelluPlas (kg $CO_{2\ eq}$)	PP (kg $CO_{2\ eq}$)
醋酸纖維素	-70	3,400
助劑	37	0
混練加工	230	0
合計	167(-95%)	3,400

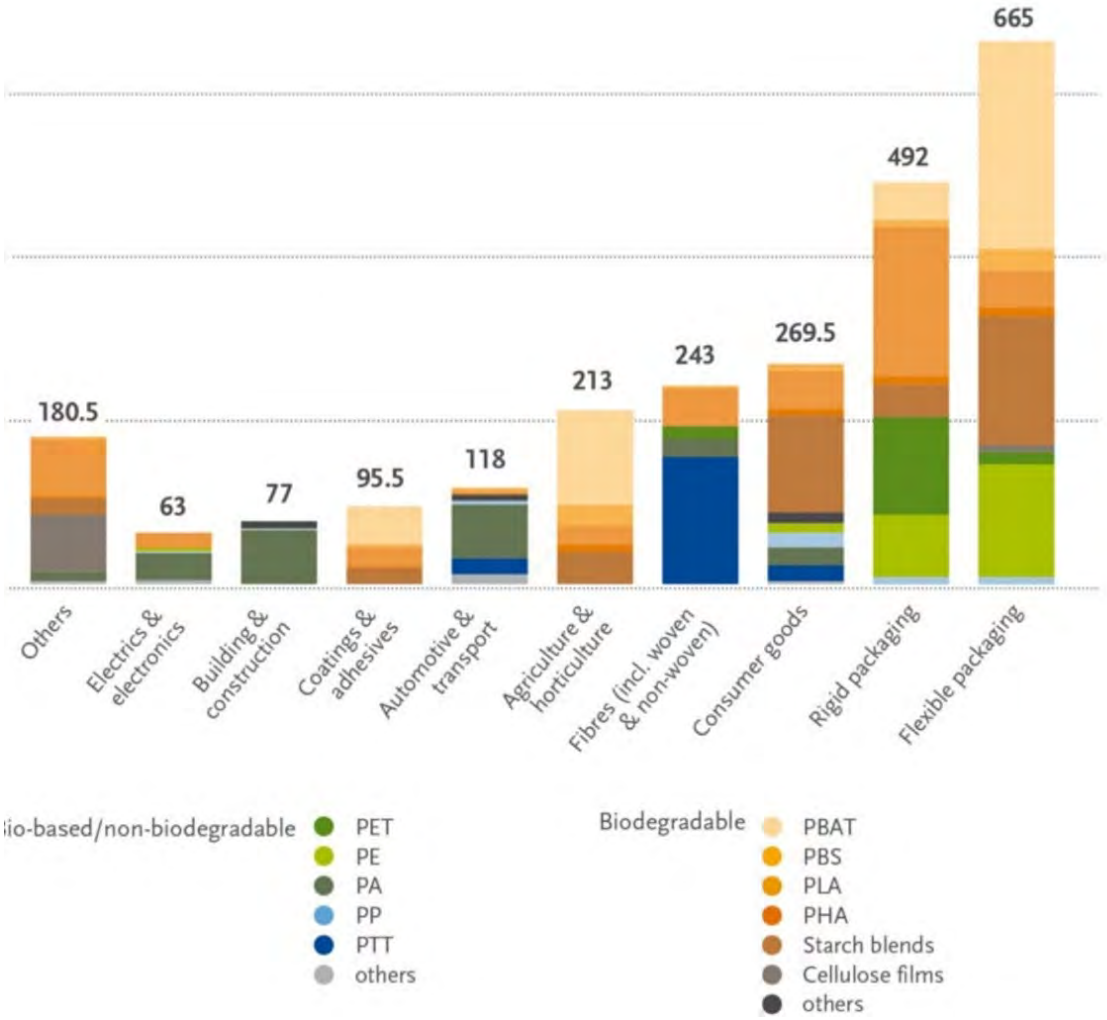
直接加工




Global production capacities of bioplastics 2021 (by material type)
Other (bio-based/ non-biodegradable) 1.0%
PE 9.5%
PET 6.2%
PA 9.1%
PP 1.9%
PEF¹ 0.0%
PTT 8.1%
Total: 242 million tonnes
19.2% PBAT
3.5% PBS
18.9% PLA
1.8% PHA
16.4% Starch blends
3.2% Cellulose films²
1.2% Other (biodegradable)
Bio-based/non-biodegradable 35.8%
Biodegradable 64.2%
¹PEF is currently in development and predicted to be available at commercial scale in 2023. ² Regenerated cellulose films
Source: European Bioplastics, nova-Institute (2021)
More information: www.european-bioplastics.org/market and www.bio-based.eu/markets


Global production capacities of bioplastics 2021 (by market segment)
in 1,000 tonnes
800
600
400
200
0
180.5
63
77
95.5
118
213
243
269.5
492
665
Others
Electrics & electronics
Building & construction
Coatings & adhesives
Automotive & transport
Agriculture & horticulture
Fibres (incl. woven & non-woven)
Consumer goods
Rigid packaging
Flexible packaging
Bio-based/non-biodegradable
PET
PE
PA
PP
PTT
others
Biodegradable
PBAT
PBS
PLA
PHA
Starch blends
Cellulose films
others
Source: European Bioplastics, nova-Institute (2021). More information: www.european-bioplastics.org/market and www.bio-based.eu/markets


1.8% PHA
16.4% Starch blends
3.2% Cellulose films[2]
1.2% Other


665
492
269.5
243
213
180.5
118
95.5
77
63
Others
Electrics & electronics
Building & construction
Coatings & adhesives
Automotive & transport
Agriculture & horticulture
Fibres (incl. woven & non-woven)
Consumer goods
Rigid packaging
Flexible packaging
io-based/non-biodegradable
PET
PE
PA
PP
PTT
others
Biodegradable
PBAT
PBS
PLA
PHA
Starch blends
Cellulose films
others

赫莉亞國際股份有限公司

- 創立於2009年的微型公司，資本額新台幣112萬元，員工3人
- 2015年開始投入熱塑性澱粉材料開發與製造
- 2017年投入醋酸纖維素膠粒開發與製造
- 2018年TPS100膠粒通過DIN CERTCO生物基材料認證
- 2019年Amyloflex 5050通過DIN CERTCO工業堆肥材料認證
- 目前，為世界上唯一具備製造熱塑性澱粉膠粒及醋酸纖維素膠粒能力的公司

徐立偉

- 英國牛津大學生化學博士（1993）
- 中國醫藥大學醫學系副教授（1994）
- 先進基因股份有限公司創辦人，董事長兼執行長（1998-2006）
- 創辦赫莉亞國際股份有限公司（2009）
- PharmEng資深顧問 （2010-2016）


TPS與Celluplas
減碳的路徑
TPS的減碳效益
CelluPlas的減碳效益
市場
徐立偉
赫莉亞
TPS與CelluPlas的減塑減碳應用
徐立偉
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