Comparative LCA of beverage cartons with and without bio-based polymers

Tetra Brik® Aseptic

Tetra Brik®

2016-05-20

IVL Swedish Environmental Resource Institute

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Project and Purpose

Life cycle assessment (LCA) was carried out for two beverage cartons containing fossil polymer (PE) and bio-based polymer (PE)

- Purpose
  - Provide knowledge of the environmental strengths and weaknesses of the Tetra Brik® and Tetra Brik Aseptic® beverage cartons with bio-based content on the relevant markets.
  - Compare the environmental performance of the carton with and without bio-based polymers.
  - Build a fact base that can be used in external communication, including comparative claims concerning the current cartons versus the redesigned.

Organisation of study

- The study was performed during 2015-2016 by Swedish Environmental Research Institute (IVL), Lisa Hallberg, on behalf of Tetra Pak

- The project participants from Tetra Pak were:
  - Davide Braghiroli and Massimiliano Cereda, Italy
  - Erika Kloow and Karin Holmkvist, Sweden
  - David Cockburn, Sweden (internal review of report)

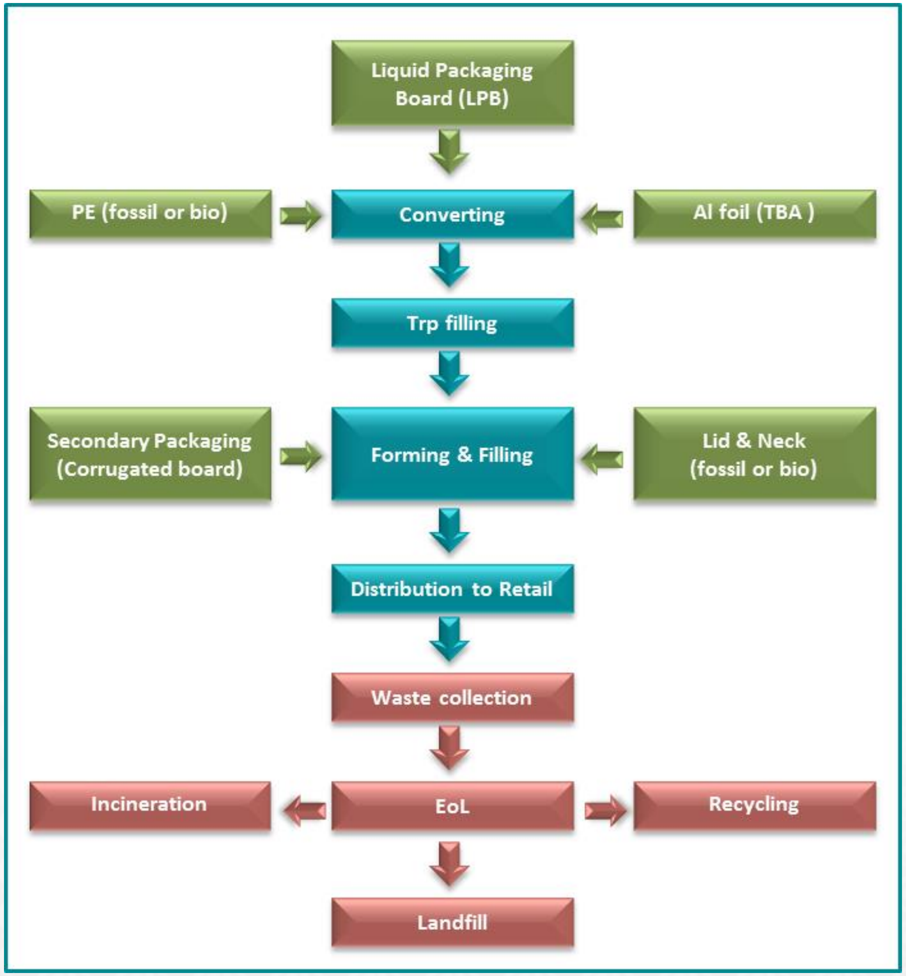
- Conducted according to the ISO standards on LCA (ISO 14040 and 14044)

- Critically reviewed by Ecoinnovazione (Alessandra Zamagni and Paolo Masoni)

Studied cartons and Flowchart

Tetra Brik® Aseptic 1000 Edge LightCap™ 30 (TBA)

Tetra Brik® 1000 Edge TwistCap™ 34 (TB)



Green processes represent raw materials, blue the core processes and red the end of life treatment.

The functional unit: the provision of 1 litres of beverage

Studied cartons: Material composition

Analysed beverage cartons	Tetra Brik Aseptic®	Tetra Brik®
Part of packaging	*Amount [g/packaging]*	*Amount [g/packaging]*
Sleeve		
Paperboard	21.6	23.1
Aluminium foil	1.4	0
Plastic	5.2	5.2
Opening		
Lid	1.4	1.4
Neck	1.6	1.3
Total weight	**31.2**	**31.0**

Scenarios

Tetra Brik® Aseptic

Part of packaging	Base case	Scenarios		
		A1	A2	A3
Lid	Fossil HDPE	Bio-based HDPE	Bio-based HDPE	Bio-based HDPE
Decor & Lamination	Fossil LDPE	Fossil LDPE	Bio-based LDPE	Bio-based LDPE
Neck	Fossil LDPE	Fossil LDPE	Fossil LDPE	Bio-based LDPE

Tetra Brik®

Part of packaging	Base case	Scenarios	
		B1	B2
Lid	Fossil HDPE	Bio-based HDPE	Bio-based HDPE
Neck	Fossil LDPE	Bio-based LDPE	Bio-based LDPE
Decor & Lamination	Fossil LDPE	Fossil LDPE	Bio-based LDPE

The base case, where only fossil PE is used, is the reference to which the bio-based PE scenarios A1-A3 (TBA) and B1-B2 (TB) are compared.

Studied markets

Four markets are studied; Sweden, Norway, Denmark and Germany. They mainly differ concerning the **end of life** treatment and the distribution of beverage cartons.

End of life scenarios

	Material recycling	Incineration with energy recovery	Incineration with no energy recovery	Landfill
Sweden (SE)	41.9%	57.3%	-	0.80%
Denmark (DK)	-	95.7%	-	4.30%
Norway (NO)	53.4%	43.3%	3.2%	0.10%
Germany (DE)	66.7%	33.3%	-	0%

The markets also differ concerning the production of the electricity used in processes such as filling, recycling and energy credit in waste incineration. Country average electricity production is applied for these processses.

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Comparisons

The bio-based PE scenarios A1-A3 (Tetra Brik® Aseptic) and B1-B2 (Tetra Brik®) are compared to the base case, where only fossil PE is used.

It is not within the scope of this study to compare:

- The two cartons with each other since they do not have the same function. The Tetra Brik® Aseptic cartons are used for ambient products, while the Tetra Brik® cartons are used for chilled products.
- The four markets are included in the study to provide a picture on the total perspective for each carton on the different markets. The markets as such should not be compared to each other.

System boundaries

- Cradle to grave study.
- Production of the beverage and refrigeration (chilled product for TB carton) are not included in the analysis.
- Substitution: Has been applied to reflect the environmental benefit associated with produced fibres (material recycling) and produced energy (end of life). This has been done by using a substitution approach, which means that the production of alternative material or energy is withdrawn from the studied system.

Biogenic carbon modelling

- **Bio-based PE:** the carbon uptake is accounted for in the production phase, as a negative biogenic CO_2 flow contributing with a negative global warming. When the biogenic carbon is released (when incinerated), these biogenic CO_2 emissions is treated in the same way as the fossil CO_2 i.e. by contributing to global warming.

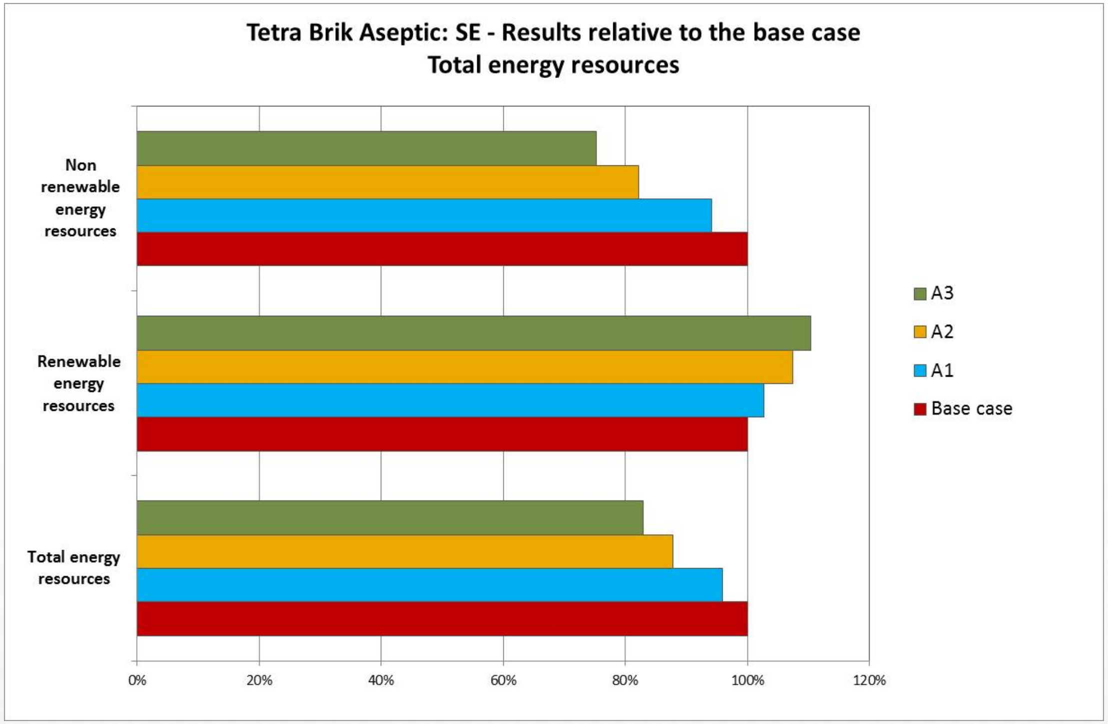
- **LPB and Secondary packaging:** the carbon uptake in the material is not included. When the biogenic carbon is released (when incinerated), these biogenic CO_2 emissions are considered not to contribute to global warming.

- It is important to point out that the choice of modelling does not affect the total results.

Tetra Brik® Aseptic, Sweden

Results relative to the base case

Total energy resources: Tetra Brik® Aseptic, Sweden



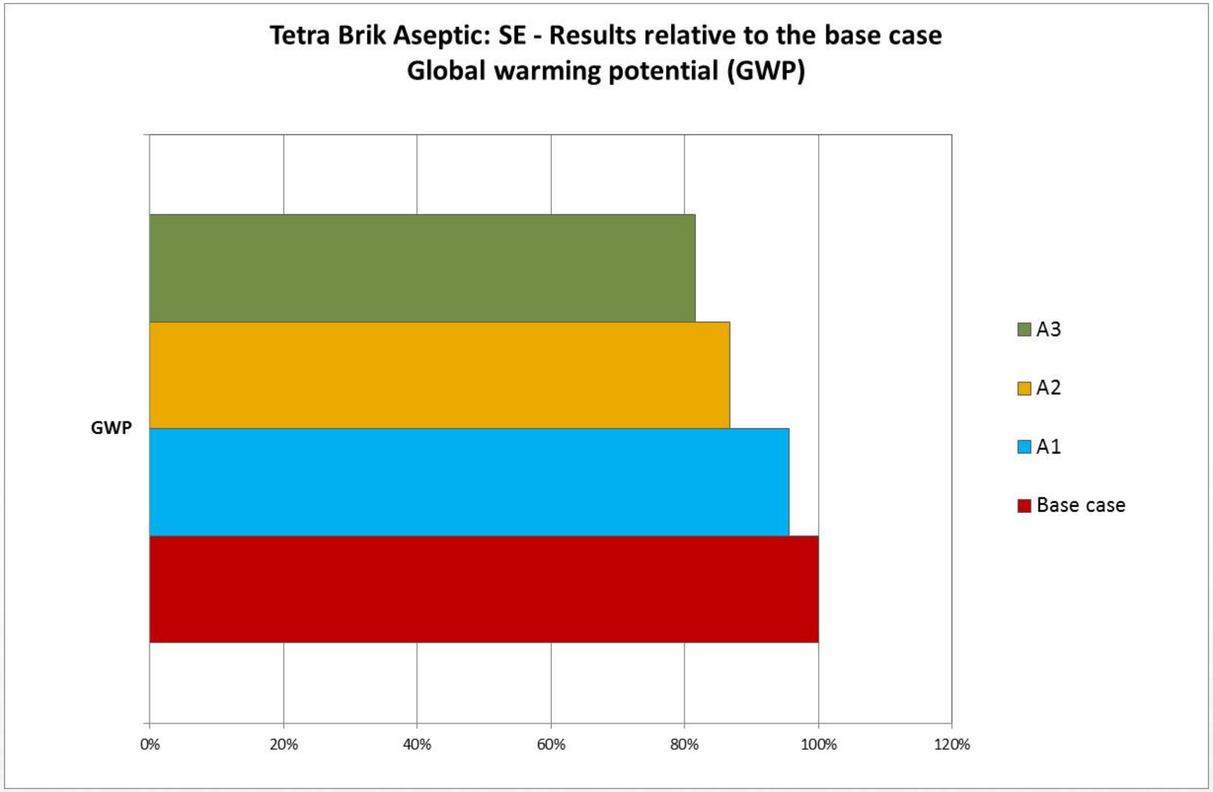
Scenario	Total energy resources	Renewable energy resources	Non renewable energy resources
Base case	100%	100%	100%
A1	96%	103%	94%
A2	88%	107%	82%
A3	83%	110%	75%

The energy use is decreasing when more bio-based PE is replacing fossil PE.

The renewable energy is increasing somewhat for the bio-based PE scenarios, but since the decrease in non renewable energy is larger, the result is a net decrease.

Results relative to the base case

Global warming potential (GWP): Tetra Brik® Aseptic, Sweden



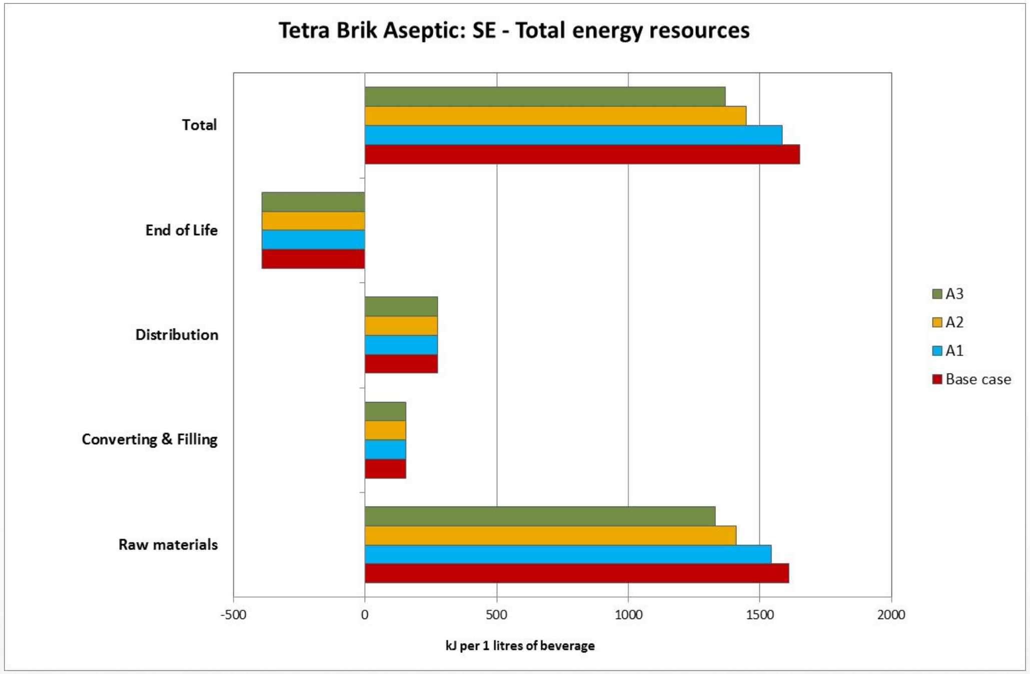
Scenario	GWP
Base case	*100%*
A1	96%
A2	87%
A3	82%

The impact is decreasing when more bio-based PE is replacing fossil PE.

For bio-based PE there is an uptake and release of carbon dioxide i.e. there is no net increase of carbon dioxide. The use of fossil PE on the other hand increases the carbon dioxide in the technosphere.

Results for the life cycle phases

Total energy resources: Tetra Brik® Aseptic, Sweden



The production of the raw materials(1) is dominating.

The EoL ends up as a net negative impact, i.e. the credits for the produced energy and paper fibres are larger than the impacts due to PE incineration and the recycling processes.

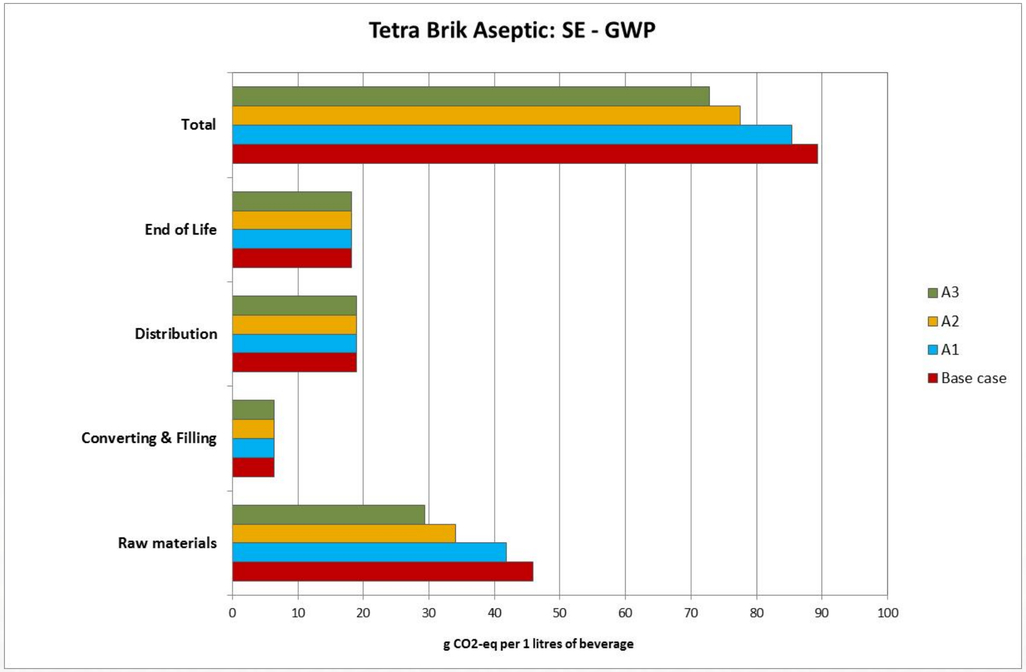
The distribution is quite large (since the beverage is included).

The converting and filling show the smallest impact, but is not negligible.

(1) The transport of bio-based PE (from Brazil) is included in the raw materials (0.3 % of the total impact for scenario A3).

Results for the life cycle phases

Global warming potential (GWP): Tetra Brik® Aseptic, Sweden



The production of the raw materials(1) is dominating.

The EoL is equal for all scenarios since the biogenic CO2 released at waste incineration contributes to GWP. This is because the uptake of the biogenic CO2 has already been accounted for in the production phase, which also explains why the impact is decreasing for the raw material production when more bio-based PE is replacing the fossil PE.

The EoL ends up as a net positive impact, i.e. the impacts due to PE incineration and the recycling processes are larger than the credits for the produced energy and paper fibres.

(1) The transport of bio-based PE (from Brazil) is included in the raw materials (0.4 % of the total impact for scenario A3).

Conclusions on results relative to the base case

Tetra Brik® Aseptic, Sweden

- The bio-based PE is to prefer when global warming and use of non renewable energy resources are considered. There is an almost 20 % impact decrease for these aspects.

- The impacts eutrophication, acidification and photo oxidant formation are much higher for the bio-based PE.
  - This is expected for EP since the bio-based PE is produced from sugar cane ethanol – a value chain containing use of fertilizers associated with phosphorous emissions as well as combustion of bio-based material giving rise to nitrogen oxide emissions (e.g. trash burning in the sugar cane fields and bagasse combustion in ethanol production).
  - There are similar reasons for the high AP impact; use of fertilizers associated (ammonia emissions) as well as combustion of bio-based material (nitrogen oxide emissions).
  - For the POCP the reasons for the higher impact are mainly the trash burning in the sugar cane fields as well as the bagasse combustion in ethanol production.

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Conclusions – Future improvements

The bio-based PE production from the sugar cane ethanol value chain is not a mature process.

The forward looking Braskem 2020 scenario showed that the environmental impacts can be decreased quite substantially.

The following future potential improvements are predicted to apply by 2020 [Braskem 2013]:

"Precision agriculture for sugarcane management (lower fertiliser inputs, lower fertiliser losses), improved sugarcane yields, full reliance on mechanical harvesting of sugarcane (no pre-harvest burning), and use of harvested trash for additional green electricity generation at ethanol mills, as well as enhanced green ethylene yields."

"Some aspects will be under Braskem's direct control whilst others relate to elsewhere in the supply chain and to the legislative/regulatory background."

"It should also be noted that the practice of trash burning is currently being phased-out in Brazilian sugarcane ethanol production and this is expected to be largely completed by 2017."

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Conclusions – Life cycle phases

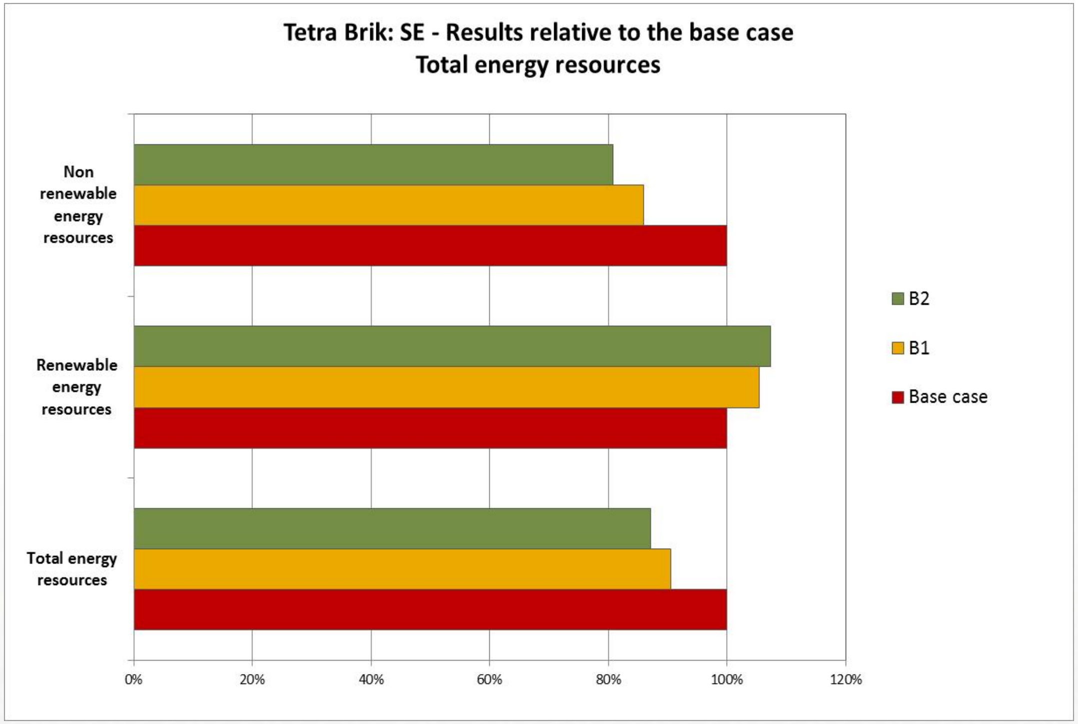
- The raw material production dominates for all impact categories.
- The distribution is a quite large part (since the beverage and secondary packaging is included in this transport).
- The end of life show a net positive impact for global warming i.e. the environmental impacts due to waste incineration and recycling are larger than the credits from the produced energy and paper fibres.
- The end of life show a net negative impact for energy resources, eutrophication, acidification and photo oxidant formation i.e. the credits from the produced energy and paper fibres are larger than the environmental impacts due to waste incineration and recycling.
- The converting and filling show the smallest impact.

The markets should not be compared, but the internal relations between the life cycle phases are of course affected by which market is analyzed due to differences in end of life management, distribution and to some extent the filling process.

Tetra Brik® Aseptic, Norway

Results relative to the base case

Total energy resources: Tetra Brik® Aseptic, Norway



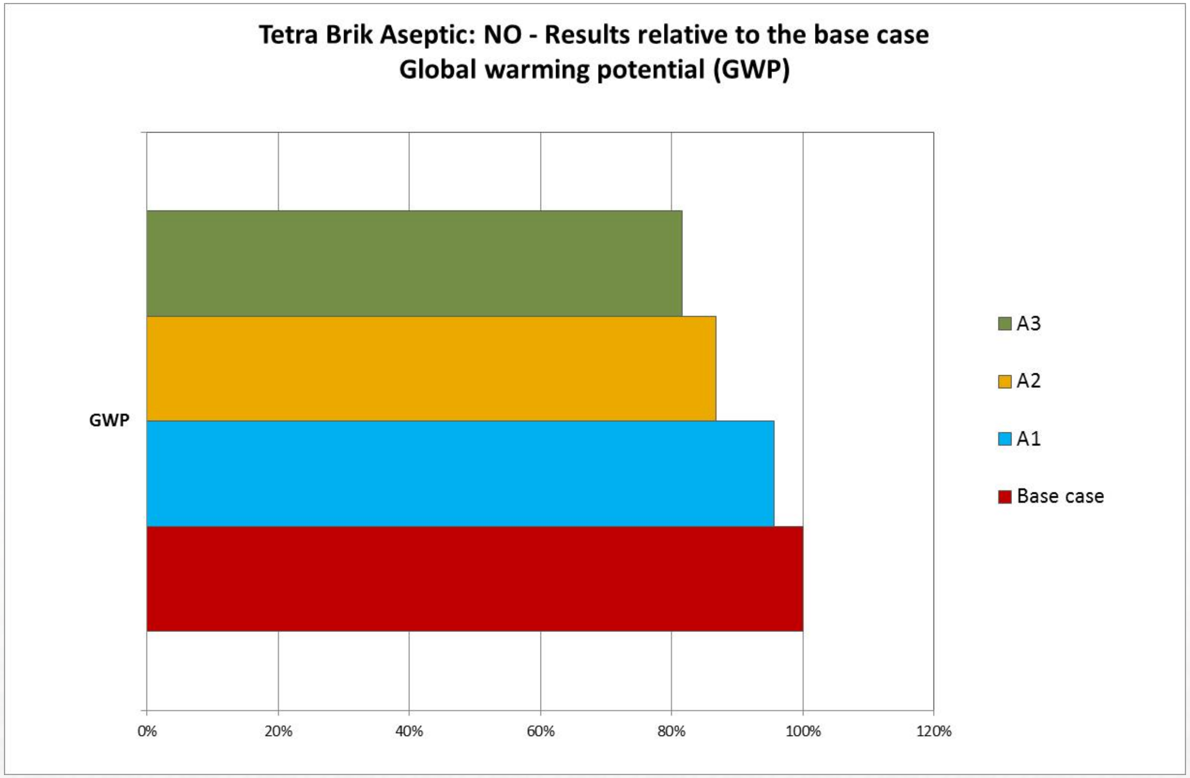
Scenario	Total energy resources	Renewable energy resources	Non renewable energy resources
Base case	100%	100%	100%
A1	96%	102%	94%
A2	88%	107%	82%
A3	84%	109%	76%

The energy use is decreasing when more bio-based PE is replacing fossil PE.

The renewable energy is increasing somewhat for the bio-based PE scenarios, but since the decrease in non renewable energy is larger, the result is a net decrease.

Results relative to the base case

Global warming potential (GWP): Tetra Brik® Aseptic, Norway



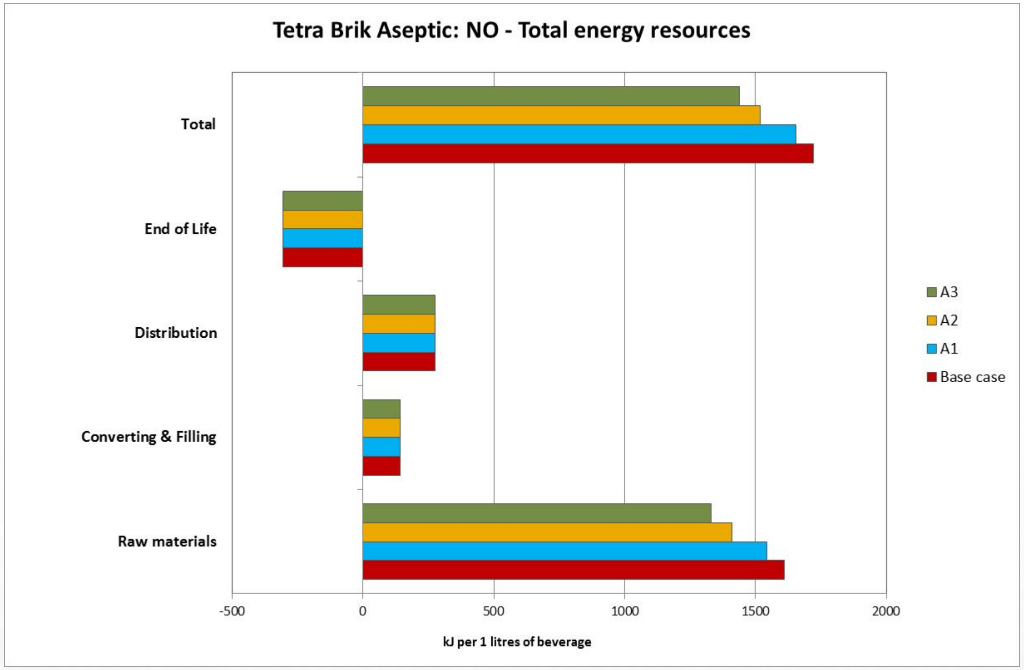
Scenario	GWP
Base case	*100%*
A1	96%
A2	87%
A3	82%

The impact is decreasing when more bio-based PE is replacing fossil PE.

For bio-based PE there is an uptake and release of carbon dioxide i.e. there is no net increase of carbon dioxide. The use of fossil PE on the other hand increases the carbon dioxide in the technosphere.

Results for the life cycle phases

Total energy resources: Tetra Brik® Aseptic, Norway



The production of the raw materials(1) is dominating.

The EoL ends up as a net negative impact, i.e. the credits for the produced energy and paper fibres are larger than the impacts due to PE incineration and the recycling processes.

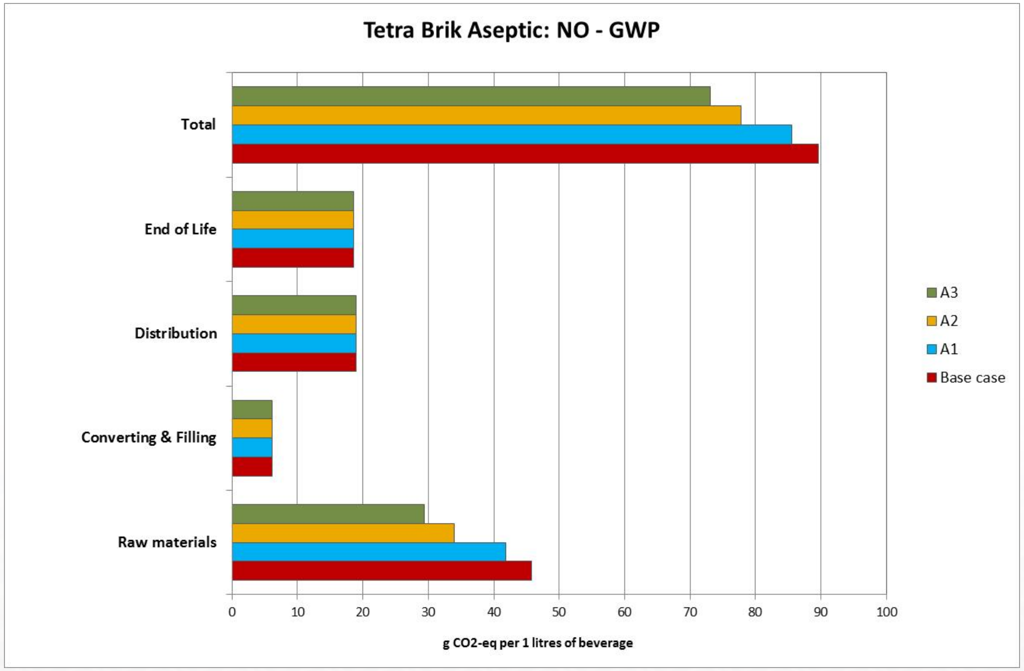
The distribution is quite large (since the beverage is included).

The converting and filling show the smallest impact, but is not negligible.

(1) The transport of bio-based PE (from Brazil) is included in the raw materials.

Results for the life cycle phases

Global warming potential (GWP): Tetra Brik® Aseptic, Norway



The production of the raw materials(1) is dominating.

The EoL is equal for all scenarios since the biogenic CO2 released at waste incineration contributes to GWP. This is because the uptake of the biogenic CO2 has already been accounted for in the production phase, which also explains why the impact is decreasing for the raw material production when more bio-based PE is replacing the fossil PE.

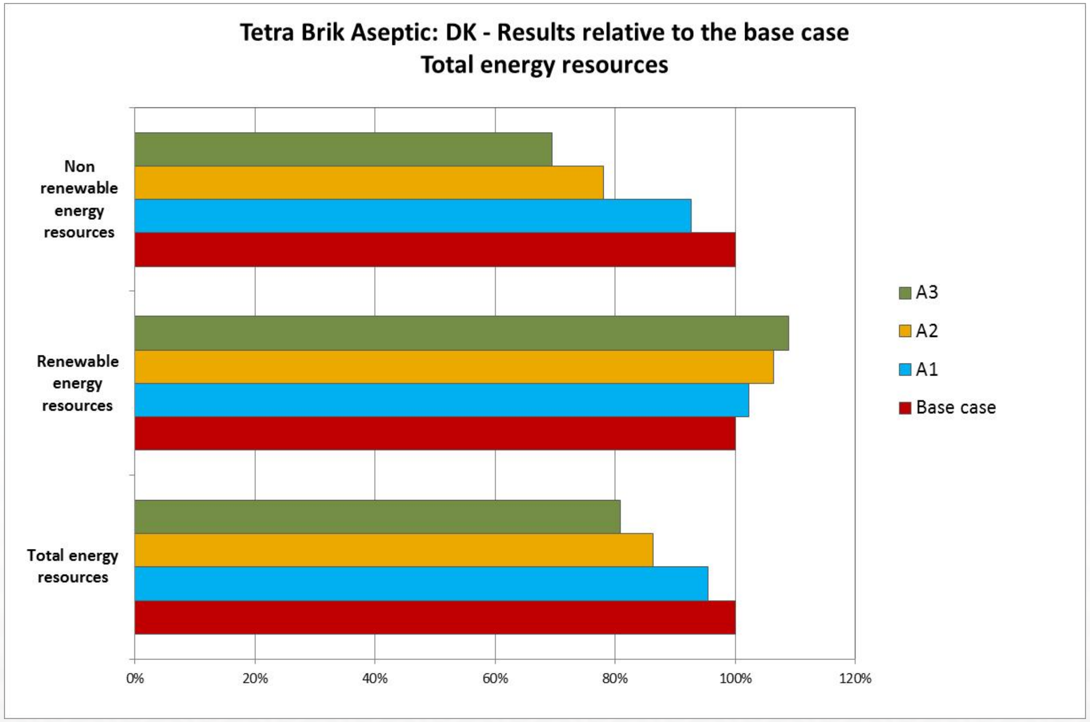
The EoL ends up as a net positive impact, i.e. the impacts due to PE incineration and the recycling processes are larger than the credits for the produced energy and paper fibres.

(1) The transport of bio-based PE (from Brazil) is included in the raw materials.

Tetra Brik® Aseptic, Denmark

Results relative to the base case

Total energy resources: Tetra Brik® Aseptic, Denmark



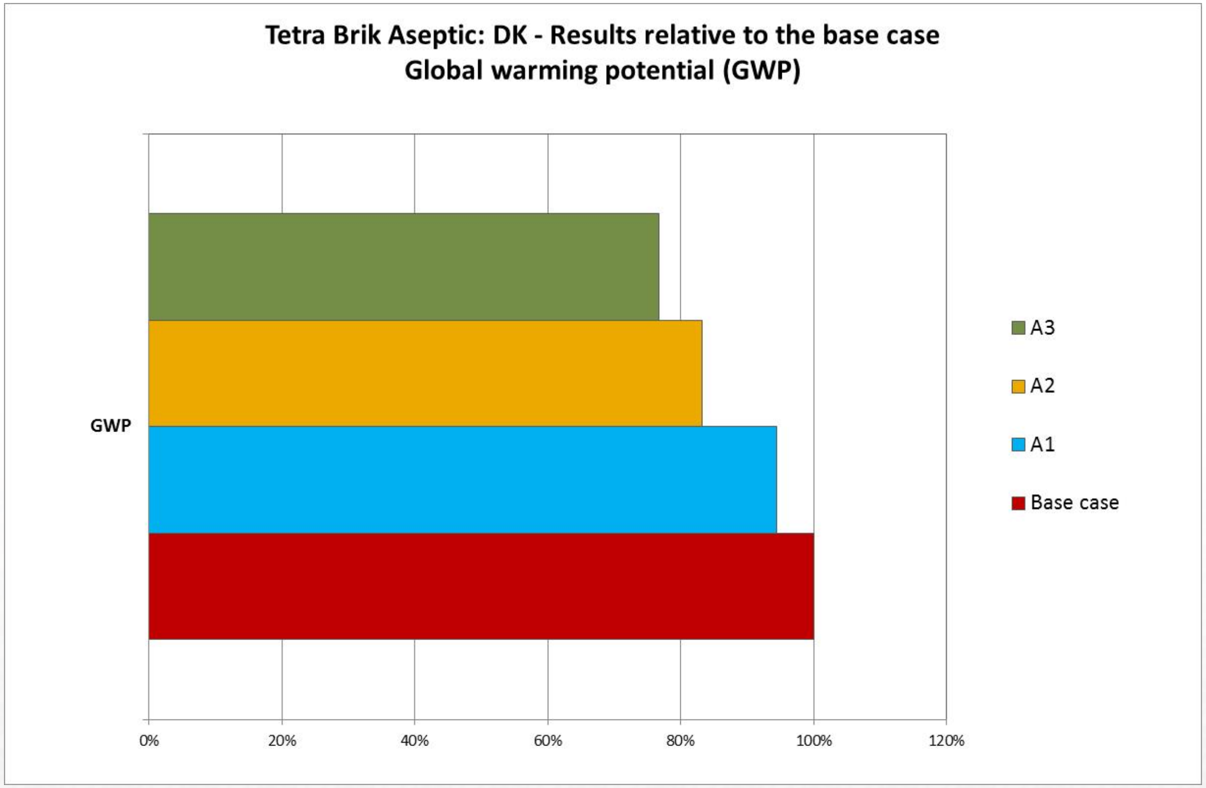
Scenario	Total energy resources	Renewable energy resources	Non renewable energy resources
Base case	100%	100%	100%
A1	95%	102%	93%
A2	86%	106%	78%
A3	81%	109%	69%

The energy use is decreasing when more bio-based PE is replacing fossil PE.

The renewable energy is increasing somewhat for the bio-based PE scenarios, but since the decrease in non renewable energy is larger, the result is a net decrease.

Results relative to the base case

Global warming potential (GWP): Tetra Brik® Aseptic, Denmark



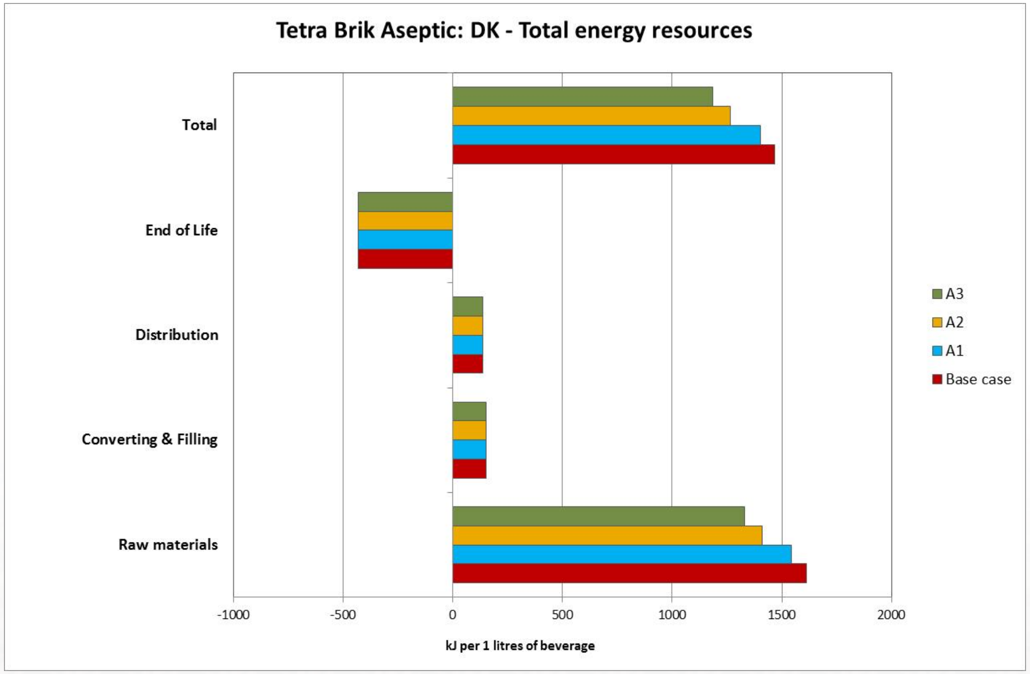
Scenario	GWP
Base case	*100%*
A1	94%
A2	83%
A3	77%

The impact is decreasing when more bio-based PE is replacing fossil PE.

For bio-based PE there is an uptake and release of carbon dioxide i.e. there is no net increase of carbon dioxide. The use of fossil PE on the other hand increases the carbon dioxide in the technosphere.

Results for the life cycle phases

Total energy resources: Tetra Brik® Aseptic, Denmark



The production of the raw materials(1) is dominating.

The EoL ends up as a net negative impact, i.e. the credits for the produced energy and paper fibres are larger than the impacts due to PE incineration and the recycling processes.

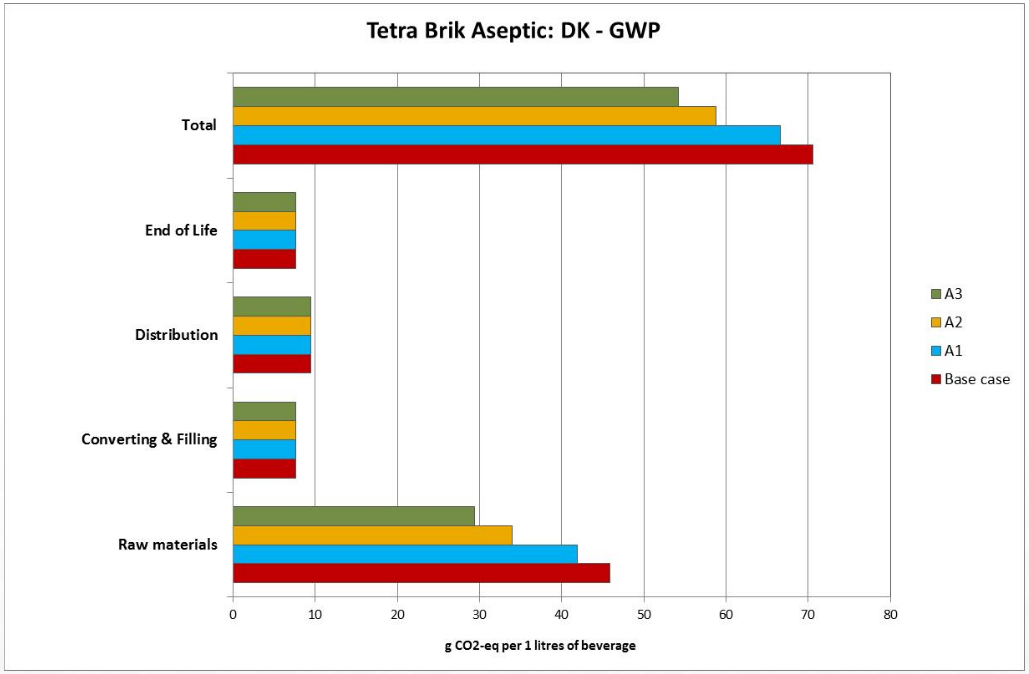
The distribution is quite large (since the beverage is included).

The converting and filling show the smallest impact, but is not negligible.

(1) The transport of bio-based PE (from Brazil) is included in the raw materials.

Results for the life cycle phases

Global warming potential (GWP): Tetra Brik® Aseptic, Denmark



The production of the raw materials(1) is dominating.

The EoL is equal for all scenarios since the biogenic CO2 released at waste incineration contributes to GWP. This is because the uptake of the biogenic CO2 has already been accounted for in the production phase, which also explains why the impact is decreasing for the raw material production when more bio-based PE is replacing the fossil PE.

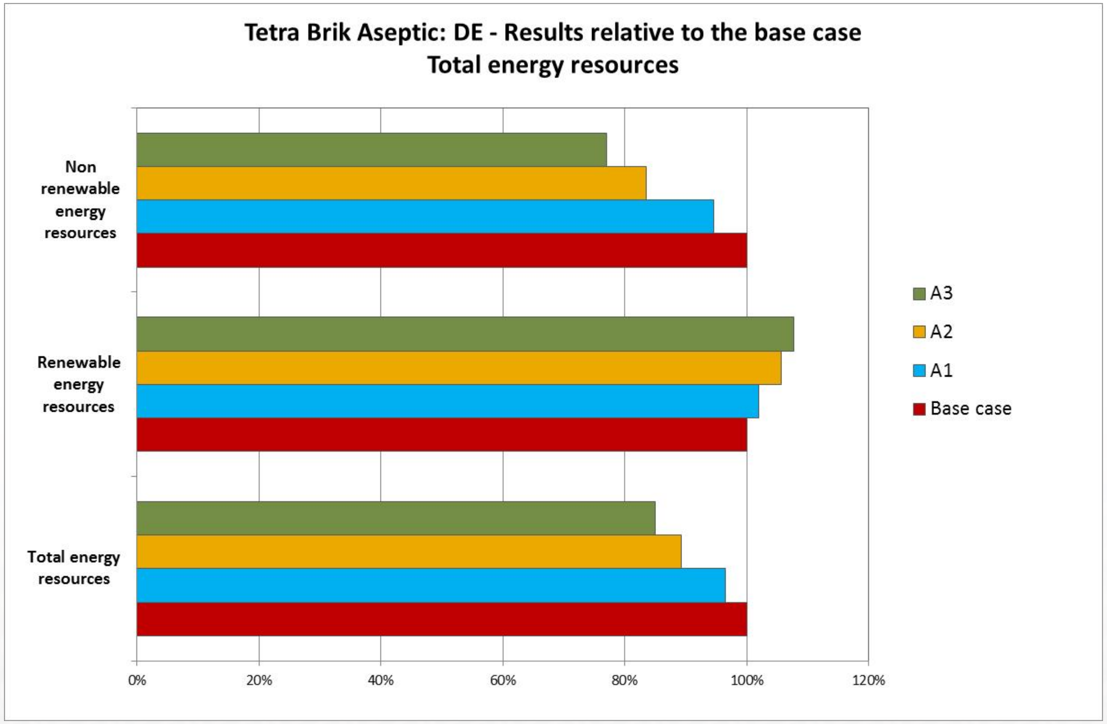
The EoL ends up as a net positive impact, i.e. the impacts due to PE incineration and the recycling processes are larger than the credits for the produced energy and paper fibres.

(1) The transport of bio-based PE (from Brazil) is included in the raw materials.

Tetra Brik® Aseptic, Germany

Results relative to the base case

Total energy resources: Tetra Brik® Aseptic, Germany



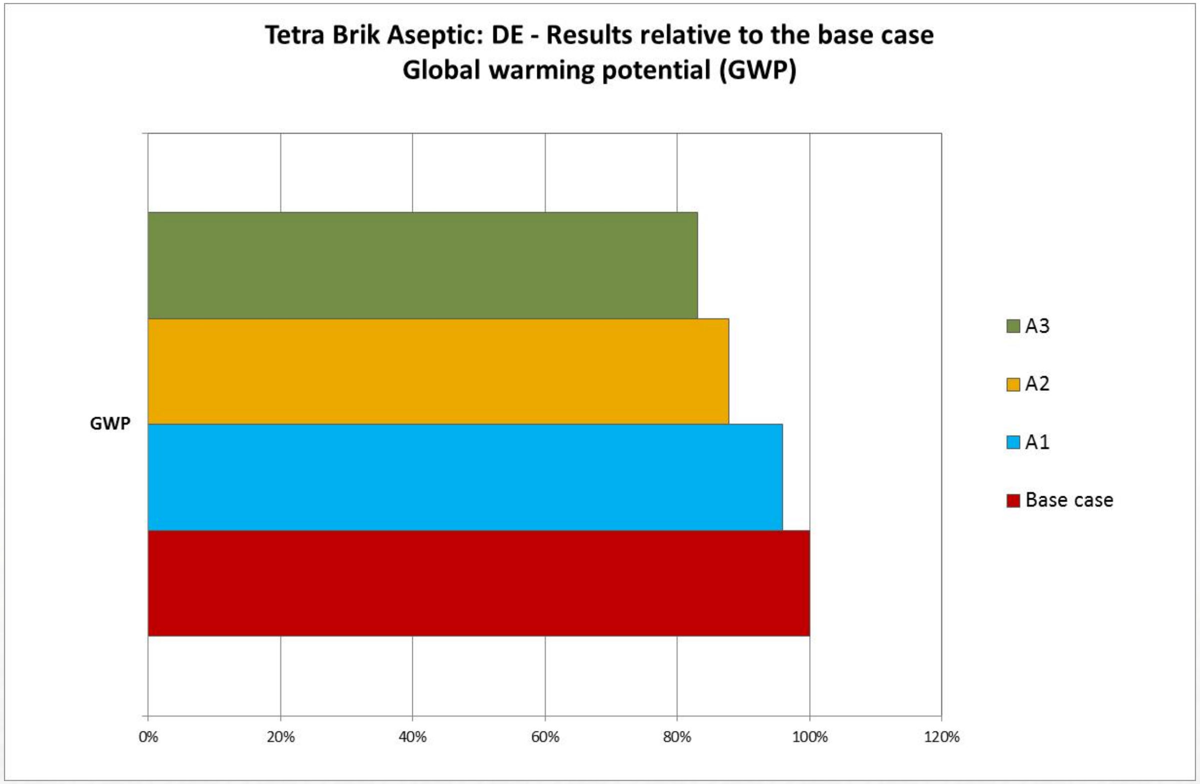
Scenario	Total energy resources	Renewable energy resources	Non renewable energy resources
Base case	*100%*	*100%*	*100%*
A1	96%	102%	95%
A2	89%	106%	84%
A3	85%	108%	77%

The energy use is decreasing when more bio-based PE is replacing fossil PE.

The renewable energy is increasing somewhat for the bio-based PE scenarios, but since the decrease in non renewable energy is larger, the result is a net decrease.

Results relative to the base case

Global warming potential (GWP): Tetra Brik® Aseptic, Germany



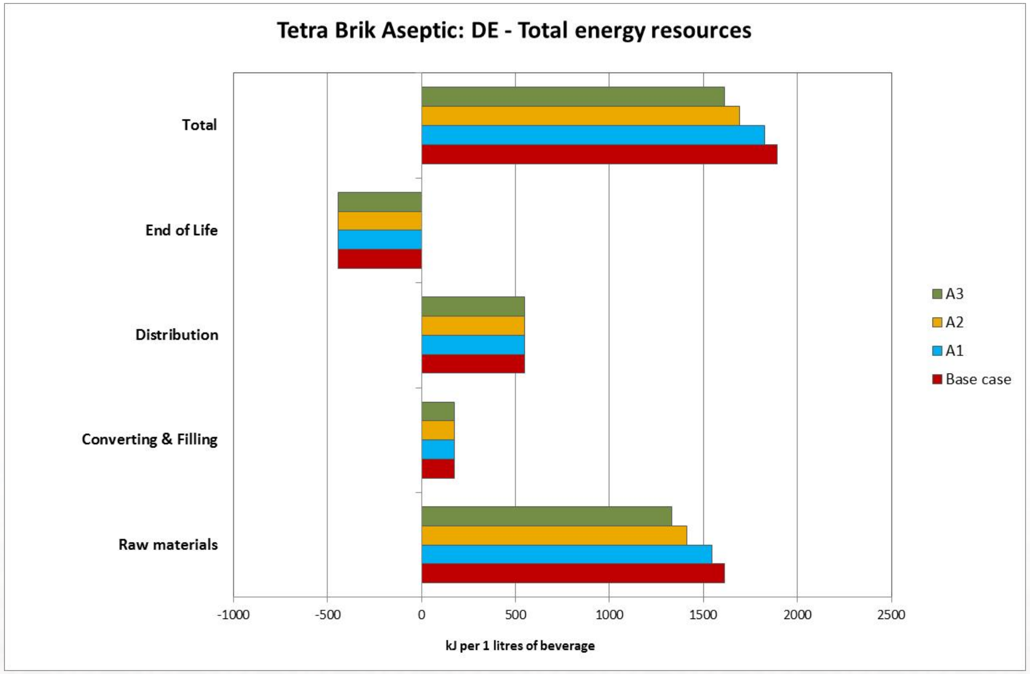
Scenario	GWP
Base case	*100%*
A1	96%
A2	88%
A3	83%

The impact is decreasing when more bio-based PE is replacing fossil PE.

For bio-based PE there is an uptake and release of carbon dioxide i.e. there is no net increase of carbon dioxide. The use of fossil PE on the other hand increases the carbon dioxide in the technosphere.

Results for the life cycle phases

Total energy resources: Tetra Brik® Aseptic, Germany



The production of the raw materials[(1)] is dominating.

The EoL ends up as a net negative impact, i.e. the credits for the produced energy and paper fibres are larger than the impacts due to PE incineration and the recycling processes.

The distribution is quite large (since the beverage is included).

The converting and filling show the smallest impact, but is not negligible.

(1) The transport of bio-based PE (from Brazil) is included in the raw materials.

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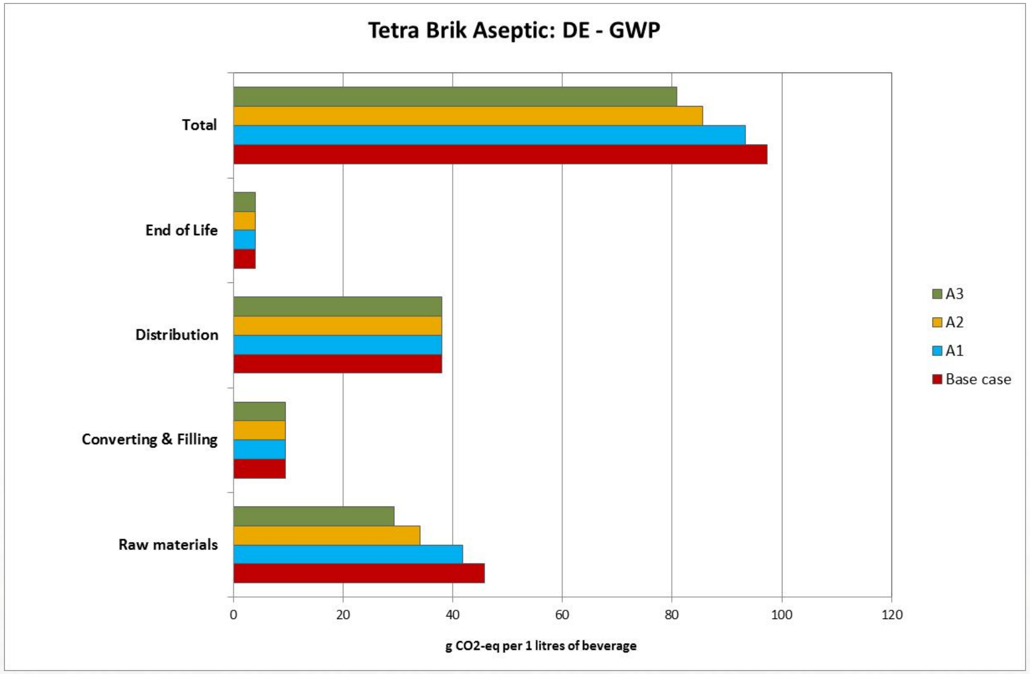
Results for the life cycle phases

Global warming potential (GWP): Tetra Brik® Aseptic, Germany



The production of the raw materials(1) is dominating.

The EoL is equal for all scenarios since the biogenic CO2 released at waste incineration contributes to GWP. This is because the uptake of the biogenic CO2 has already been accounted for in the production phase, which also explains why the impact is decreasing for the raw material production when more bio-based PE is replacing the fossil PE.

The EoL ends up as a net positive impact, i.e. the impacts due to PE incineration and the recycling processes are larger than the credits for the produced energy and paper fibres.

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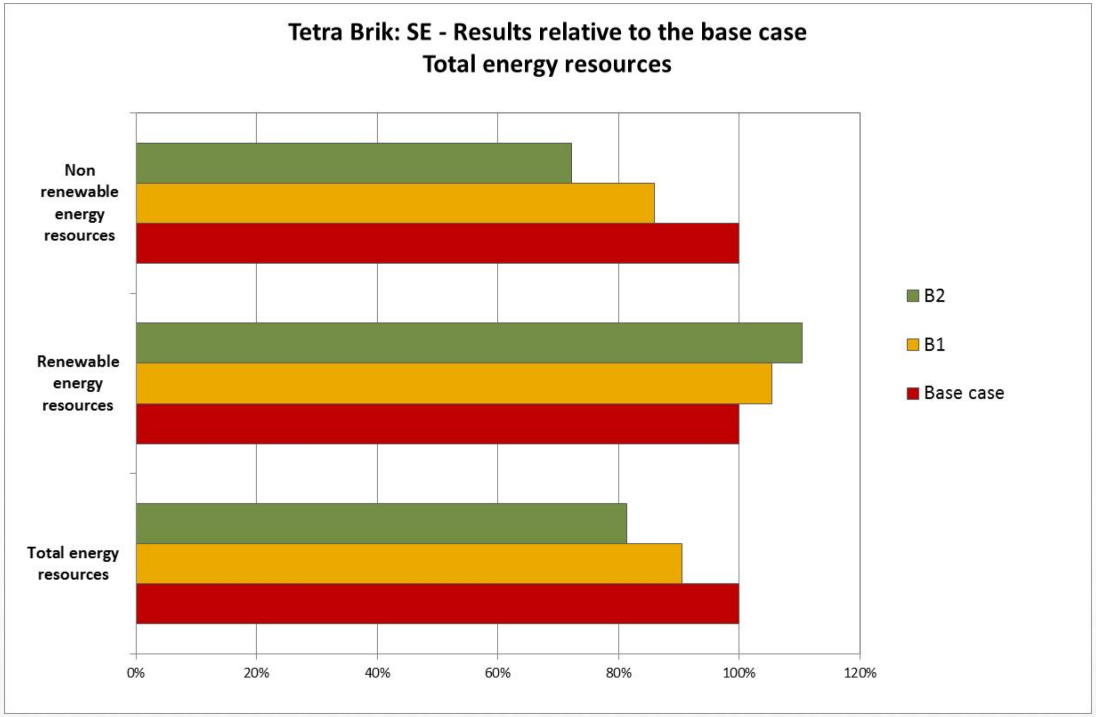
Tetra Brik®, Sweden

Results relative to the base case

Total energy resources: Tetra Brik®, Sweden



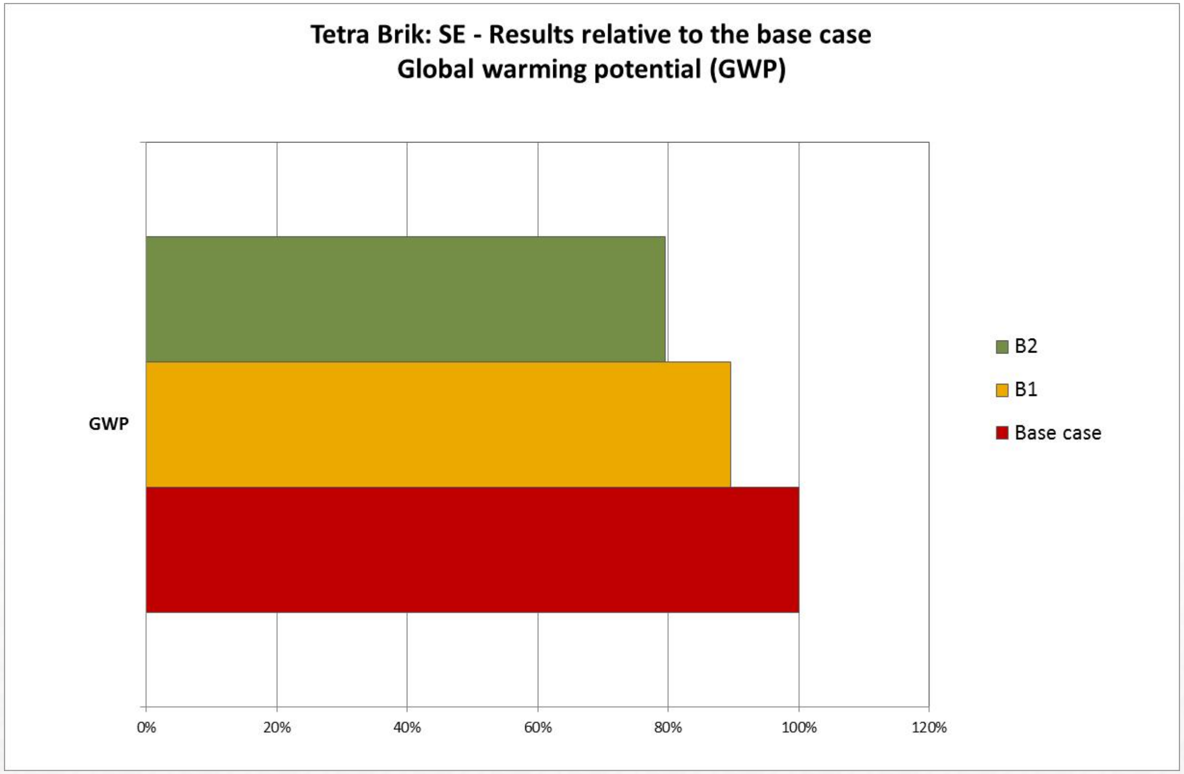
Scenario	Total energy resources	Renewable energy resources	Non renewable energy resources
Base case	100%	100%	100%
B1	91%	105%	86%
B2	81%	110%	72%

The energy use is decreasing when more bio-based PE is replacing fossil PE.

The renewable energy is increasing somewhat for the bio-based PE scenarios, but since the decrease in non renewable energy is larger, the result is a net decrease.

Results relative to the base case

Global warming potential (GWP): Tetra Brik®, Sweden



Scenario	GWP
Base case	*100%*
B1	90%
B2	80%

The impact is decreasing when more bio-based PE is replacing fossil PE.

For bio-based PE there is an uptake and release of carbon dioxide i.e. there is no net increase of carbon dioxide. The use of fossil PE on the other hand increases the carbon dioxide in the technosphere.

Conclusions on results relative to the base case

Tetra Brik®, Sweden

- The bio-based PE is to prefer when global warming and use of non renewable energy resources are considered. There is an impact decrease of 20 % for GWP and 28 % for non renewable energy.

- The impacts eutrophication, acidification and photo oxidant formation are much higher for the bio-based PE.
  - This is expected for EP since the bio-based PE is produced from sugar cane ethanol – a value chain containing use of fertilizers associated with phosphorous emissions as well as combustion of bio-based material giving rise to nitrogen oxide emissions (e.g. trash burning in the sugar cane fields and bagasse combustion in ethanol production).
  - There are similar reasons for the high AP impact; use of fertilizers associated (ammonia emissions) as well as combustion of bio-based material (nitrogen oxide emissions).
  - For the POCP the reasons for the higher impact are mainly the trash burning in the sugar cane fields as well as the bagasse combustion in ethanol production.

Conclusions – Life cycle phases

- The raw material production dominates for all impact categories.
- The distribution is a quite large part (since the beverage and secondary packaging is included in this transport).
- The end of life show a net positive impact for global warming i.e. the environmental impacts due to waste incineration and recycling are larger than the credits from the produced energy and paper fibres.
- The end of life show a net negative impact for energy resources, eutrophication, acidification and photo oxidant formation i.e. the credits from the produced energy and paper fibres are larger than the the environmental impacts due to waste incineration and recycling.
- The converting and filling show the smallest impact.

The markets should not be compared, but the internal relations between the life cycle phases are of course affected by which market is analyzed due to differences in end of life management, distribution and to some extent the filling process.

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Conclusions – Future improvements

The bio-based PE production from the sugar cane ethanol value chain is not a mature process.

A forward looking scenario for 2020 made in the Braskem LCA showed that the environmental impacts can be decreased quite substantially.

The following future potential improvements are predicted to apply by 2020 [Braskem 2013]:

“Precision agriculture for sugarcane management (lower fertiliser inputs, lower fertiliser losses), improved sugarcane yields, full reliance on mechanical harvesting of sugarcane (no pre-harvest burning), and use of harvested trash for additional green electricity generation at ethanol mills, as well as enhanced green ethylene yields.”

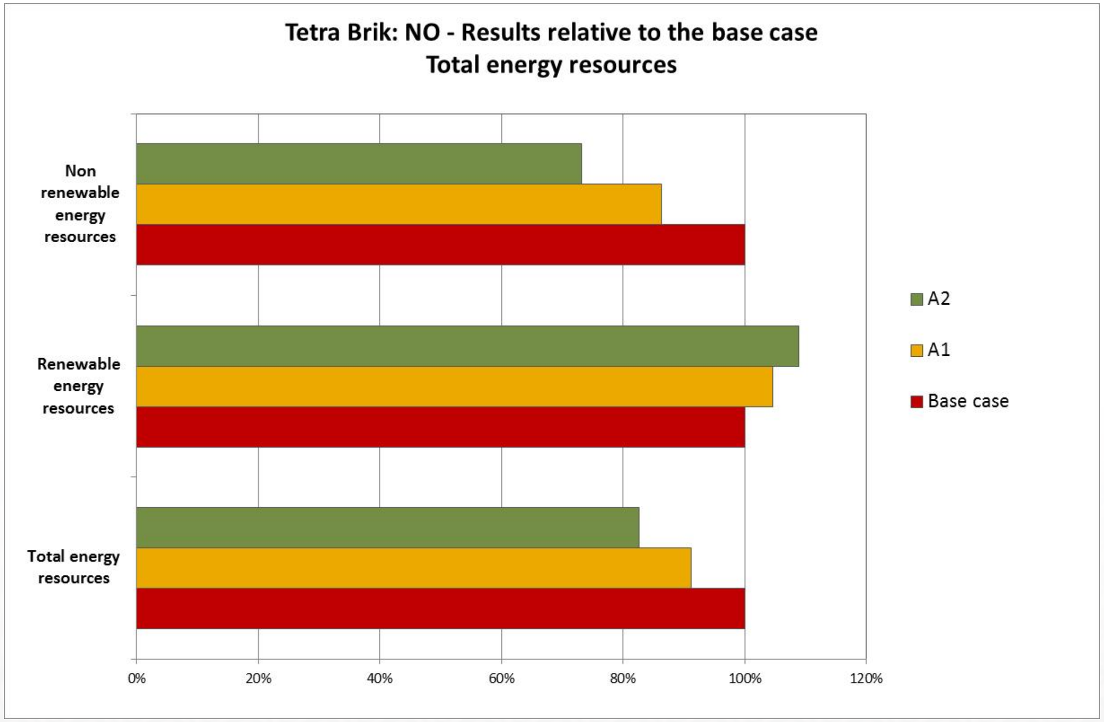
“Some aspects will be under Braskem’s direct control whilst others relate to elsewhere in the supply chain and to the legislative/regulatory background.”

“It should also be noted that the practice of trash burning is currently being phased-out in Brazilian sugarcane ethanol production and this is expected to be largely completed by 2017.”

Tetra Brik®, Norway

Results relative to the base case

Total energy resources: Tetra Brik®, Norway



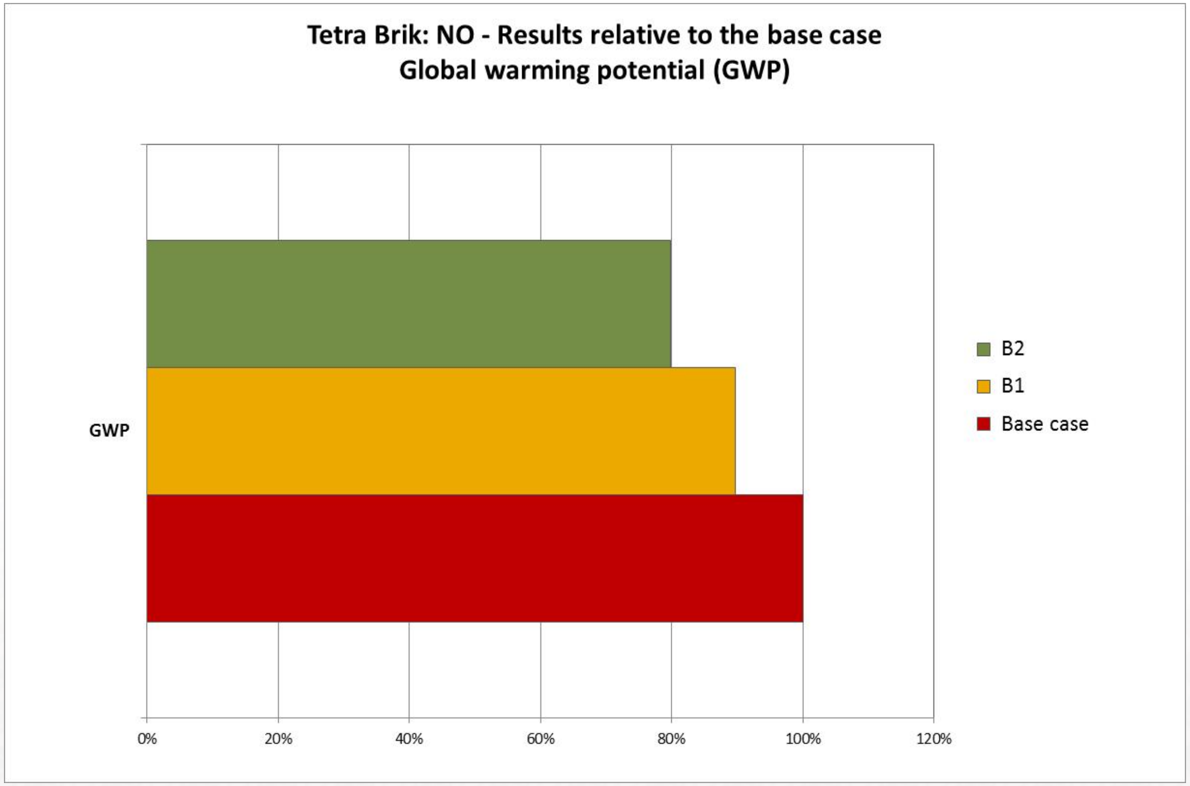
Scenario	Total energy resources	Renewable energy resources	Non renewable energy resources
Base case	100%	100%	100%
B1	91%	105%	86%
B2	83%	109%	73%

The energy use is decreasing when more bio-based PE is replacing fossil PE.

The renewable energy is increasing somewhat for the bio-based PE scenarios, but since the decrease in non renewable energy is larger, the result is a net decrease.

Results relative to the base case

Global warming potential (GWP): Tetra Brik®, Norway



Scenario	GWP
Base case	*100%*
B1	90%
B2	80%

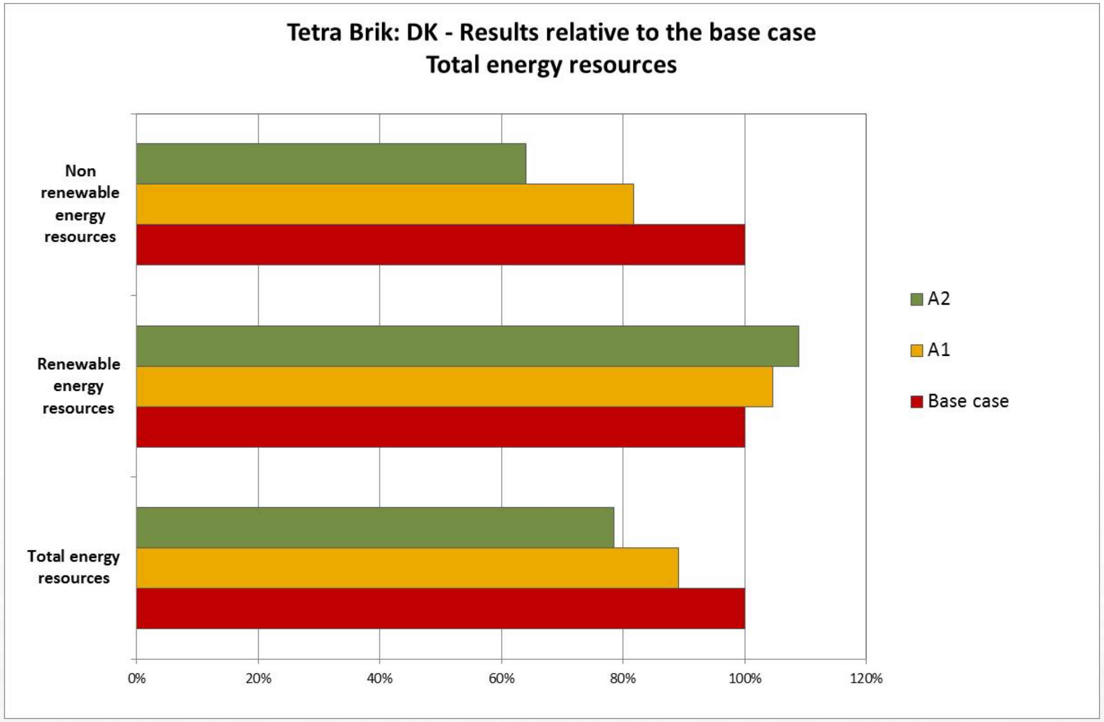
The impact is decreasing when more bio-based PE is replacing fossil PE.

For bio-based PE there is an uptake and release of carbon dioxide i.e. there is no net increase of carbon dioxide. The use of fossil PE on the other hand increases the carbon dioxide in the technosphere.

Tetra Brik®, Denmark

Results relative to the base case

Total energy resources: Tetra Brik®, Denmark



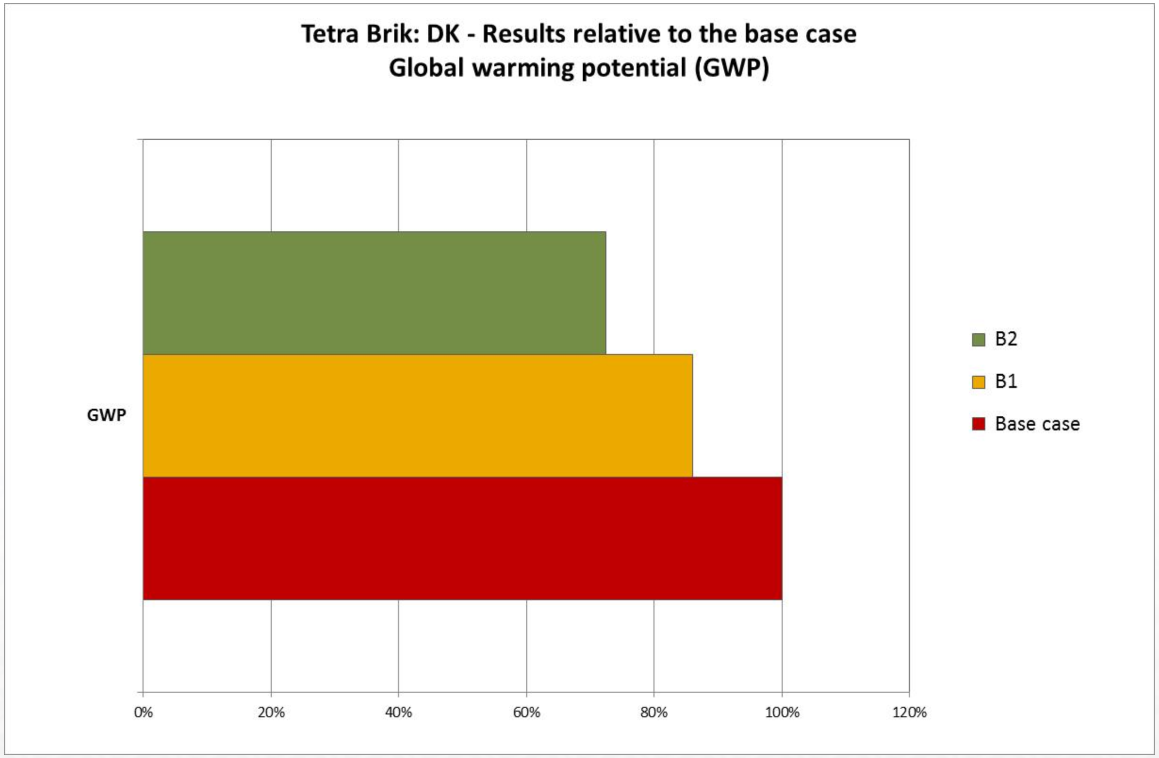
Scenario	Total energy resources	Renewable energy resources	Non renewable energy resources
Base case	100%	100%	100%
B1	89%	105%	82%
B2	79%	109%	64%

The energy use is decreasing when more bio-based PE is replacing fossil PE.

The renewable energy is increasing somewhat for the bio-based PE scenarios, but since the decrease in non renewable energy is larger, the result is a net decrease.

Results relative to the base case

Global warming potential (GWP): Tetra Brik®, Denmark



Scenario	GWP
Base case	*100%*
B1	86%
B2	72%

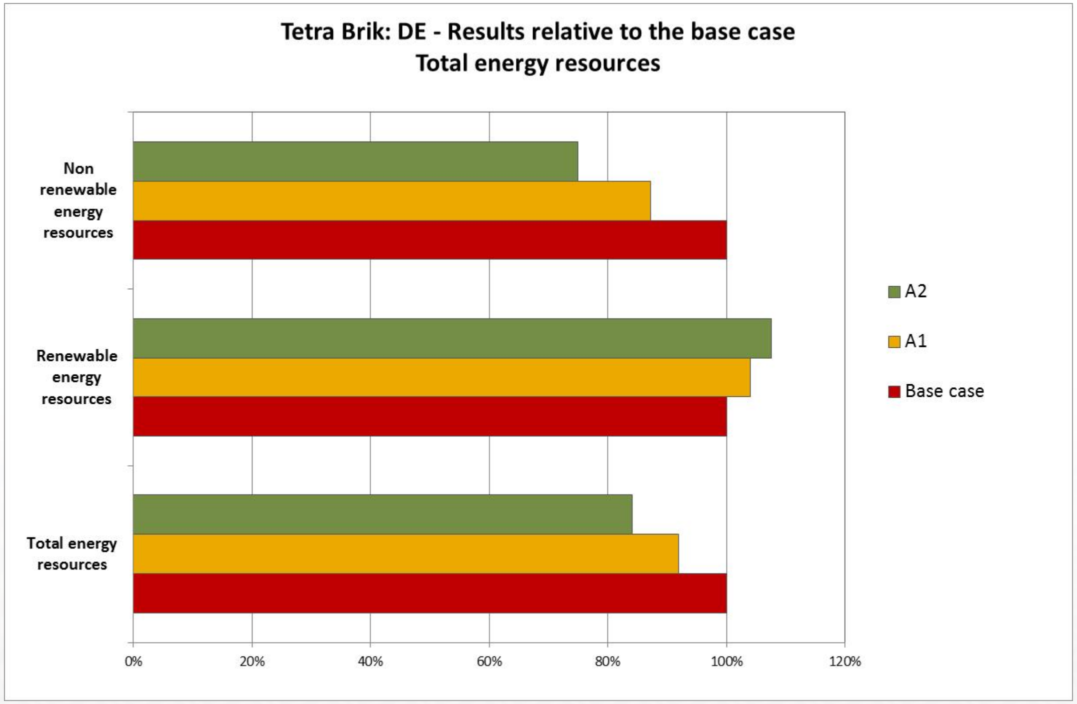
The impact is decreasing when more bio-based PE is replacing fossil PE.

For bio-based PE there is an uptake and release of carbon dioxide i.e. there is no net increase of carbon dioxide. The use of fossil PE on the other hand increases the carbon dioxide in the technosphere.

Tetra Brik®, Germany

Results relative to the base case

Total energy resources: Tetra Brik®, Germany



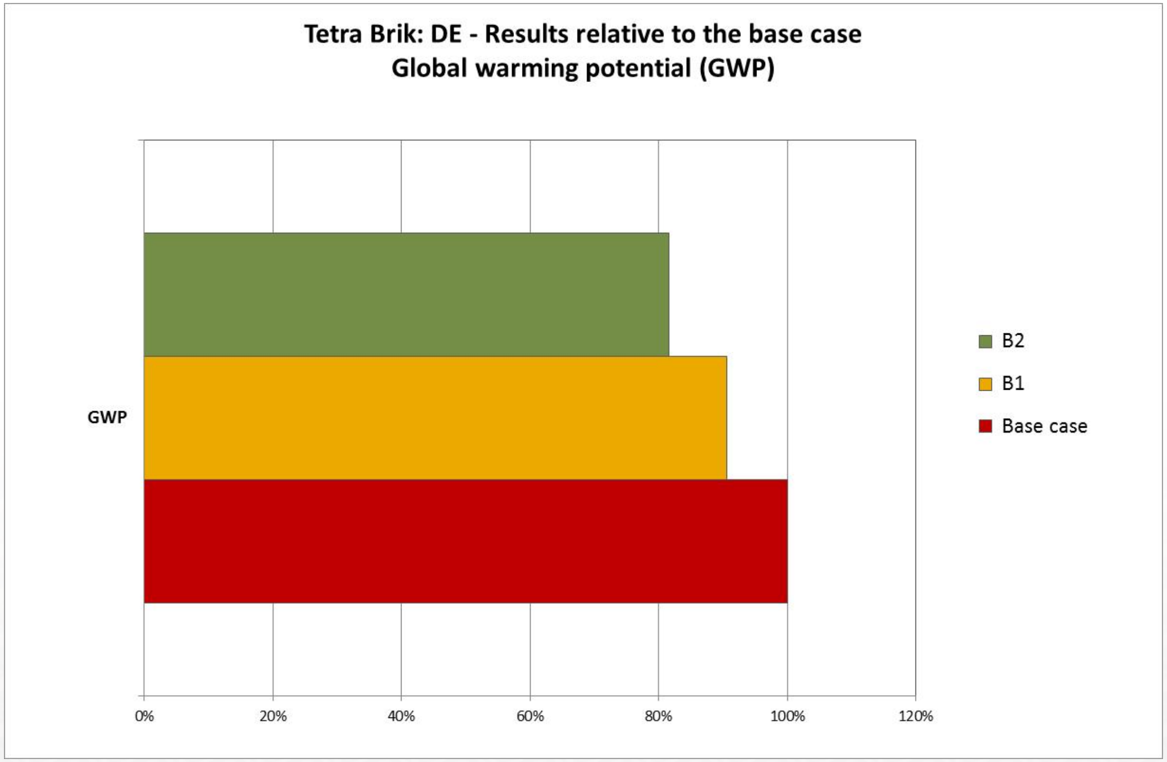
Scenario	Total energy resources	Renewable energy resources	Non renewable energy resources
Base case	*100%*	*100%*	*100%*
B1	92%	104%	87%
B2	84%	108%	75%

The energy use is decreasing when more bio-based PE is replacing fossil PE.

The renewable energy is increasing somewhat for the bio-based PE scenarios, but since the decrease in non renewable energy is larger, the result is a net decrease.

Results relative to the base case

Global warming potential (GWP): Tetra Brik®, Germany



Scenario	GWP
Base case	*100%*
B1	91%
B2	82%

The impact is decreasing when more bio-based PE is replacing fossil PE.

For bio-based PE there is an uptake and release of carbon dioxide i.e. there is no net increase of carbon dioxide. The use of fossil PE on the other hand increases the carbon dioxide in the technosphere.

Life cycle assessment (LCI/LCA)

Definitions

- **"Cradle to grave":** When including the whole life cycle.

- **"Cradle to gate":** When including everything up to the factory "gate".
- **Life cycle inventory (LCI):** When just presenting the inventory results in terms of kg of emissions (CO2, NOx, SO2 etc.) & resources (Crude oil, Uranium etc.)
- **Life cycle impact assessment (LCIA):** When also presenting the impact assessment results in terms of Global warming (kg CO_2 equvivalents), Acidification (kg SO_2 equvivalents), Eutrophication (kg PO_4^{3-} equvivalents) etc.
- **Functional unit:** defines the quantification of the function of the product. It is a scale factor, which has to be the same for the different systems studied e.g. 1 tonne of steel product.

Life cycle impact assessment (LCIA)