The Water, Energy and Carbon Footprints of Locally Produced Tomato Paste in the UK

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Outline

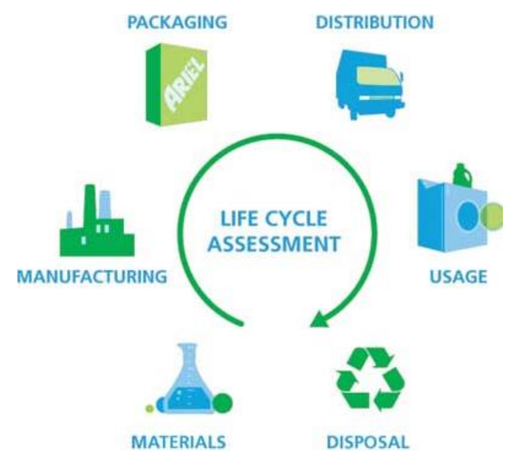
- Importance of water/energy /carbon footprint for local food productions (tomato paste)
- Key Facts/Questions?
- Aim/objectives
- Tomato paste production
- Methodology
  - Case study
- Results
  - Locally produced or Imported tomato paste?
- Conclusions

Water-energy-carbon Nexus/Footprint

- Water-energy nexus can be important when **production** and **consumption** are **far** from each other.
- **Tomato cultivation** is in heated greenhouses/ open field-grown/unheated greenhouses.
- Heated greenhouses: **energy demanding** for heating, intense cultivation, less water demand.
- Open-field: Water abstraction is **energy-intensive, Water-intensive** for irrigation, adverse effect on **vulnerable** resources

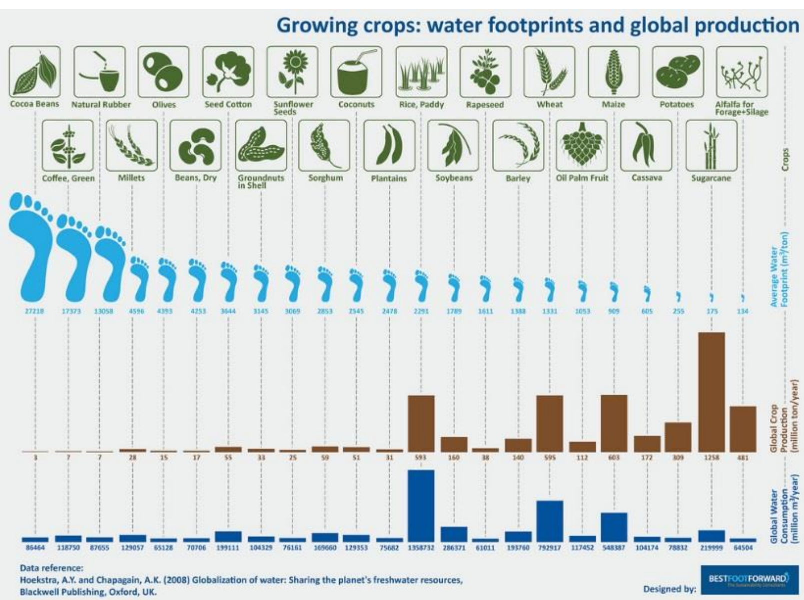
Methods/key points in evaluation water, energy and carbon footprints

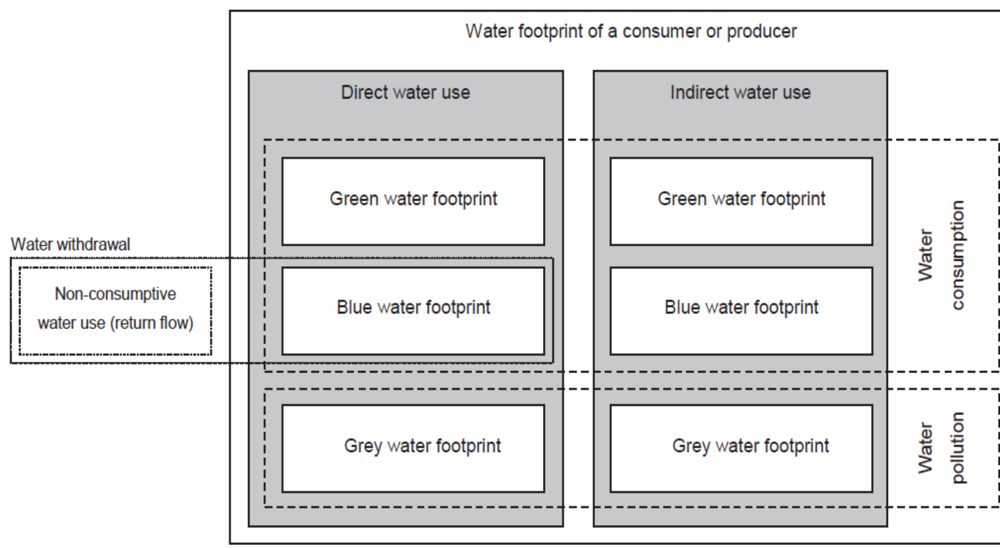
- **The water/energy/carbon footprint is an indicator for direct and indirect freshwater/energy/carbon emission (CO_2) used to produce a unit volume/mass of product over full supply chain.**
- **The water in cultivation phase of food supply chains usually accounts for the highest proportion of the water footprint.**
- **Life Cycle Assessment (LCA) is a common approach for evaluation of the environmental impacts over life cycle ('cradle to grave').**



Water footprint

- Definitions: Volume of freshwater used over the full supply chain of a product (blue, green and grey water);
- Blue water: surface (e.g. lake, river) and underground sources.
- Green water: rainwater (not runoff) and is renewable.
- Grey water: freshwater required to assimilate the load of pollutants based on existing ambient water quality standards.

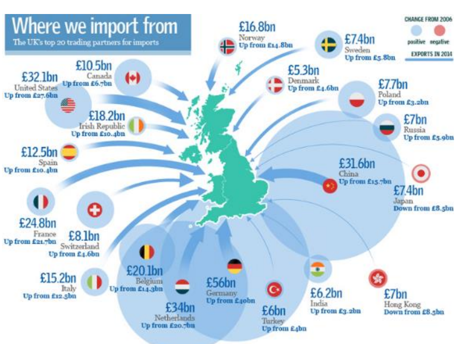




Key Facts/Questions?

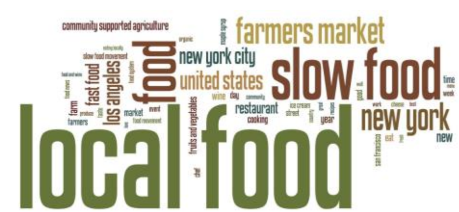
- **LCA focused on either cultivation or manufacturing.**
- **The LCA of both phases with transportation received less attention especially for local food productions!**
- **Some foods are processed far from consumption!**
- **Local or imported food production: Which one is better?**
- **in terms of more sustainable/water/energy/carbon footprint?**


Imported processed food production



Transition to

Locally produced/ processed food production



Aim/objectives

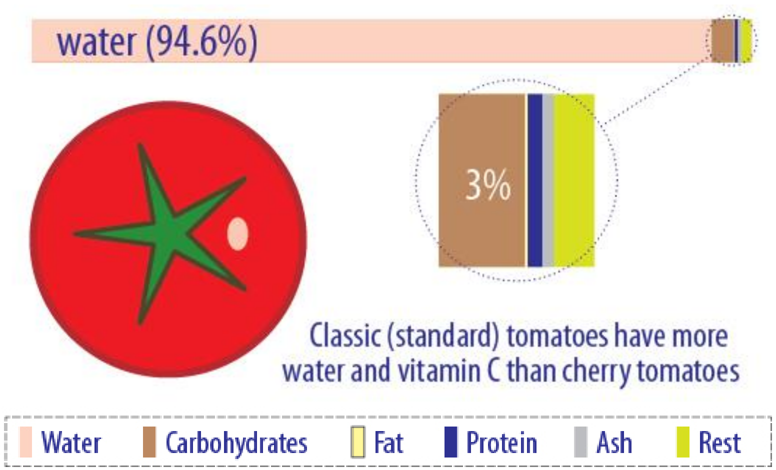
- For tomato paste, both cultivation and manufacturing phases are in the same geographical area due to short shelf-life of tomatoes.
- Explore implications of locally produced tomato paste in terms of water/energy/carbon footprints compared to imported products.
- Conduct complete LCA of tomato paste production for both scenarios.

Transition ***towards local food production***

Tomato Paste/water footprint

- Two parts: tomato cultivation and tomato processing
- Tomatoes contain approximately up to 95% water and 5% solids/sugars;
- Water footprint of tomato puree/paste is almost 99% for cultivation phase and around 1% for processing phase;
- Global average water footprint for fresh tomato is 214 m^3/tonne while this rate for UK average is only around 5% (i.e. 12 m^3/tonne).

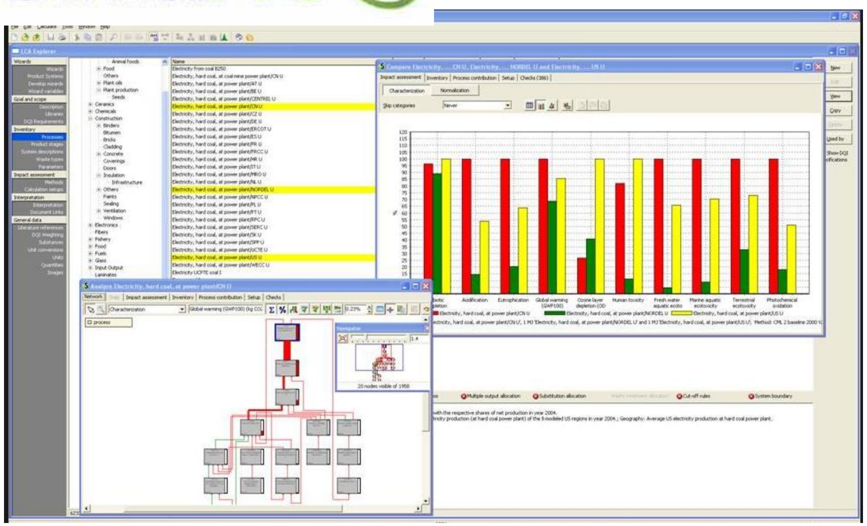
Product	World	UK	Oxfordshire	Cambridgeshire
Tomato fresh	214	12	13	13
Tomato juice, concentrated	1069	61	68	64
Tomato paste	**855**	**50**	**54**	**52**
Tomato ketchup	534	30	33	33
Tomato puree	713	40	45	43
Peeled tomatoes	267	15	17	15
Tomato, dried	4276	244	270	259

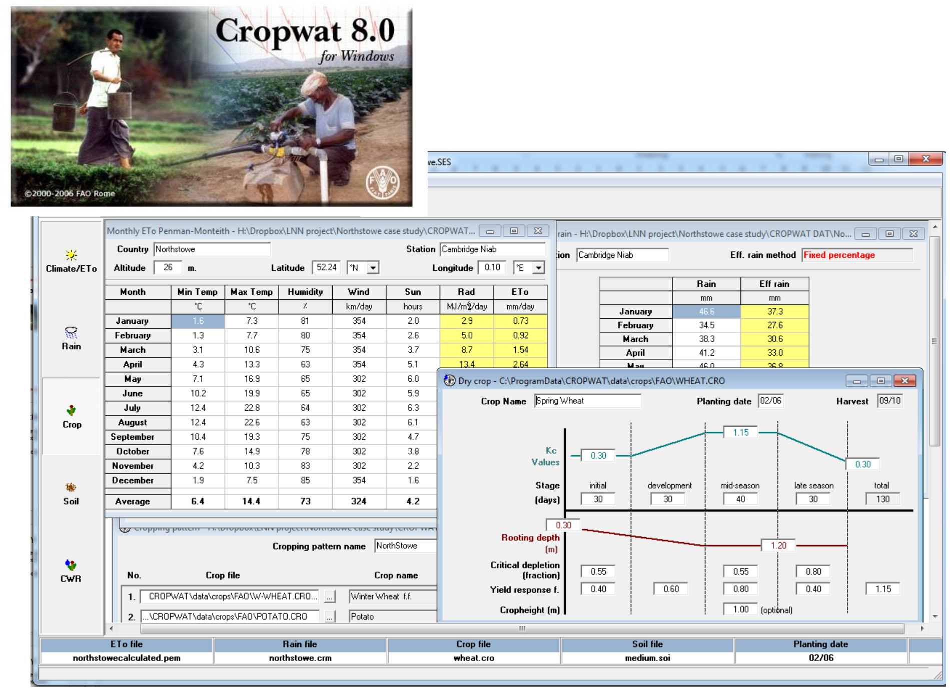


Methodology

- **LCA modelling of tomato paste using Simapro in four phases:**
  1-cultivation, 2-manufacturing, 3-packaging, 4-transport;
- **CROPWAT model for water demand estimation of cultivation.**

SimaPro





SimaPro is a commonly used LCA tool for quantifying environmental impacts including the energy and carbon footprints of a product.

Case Study

- Tomato paste is currently imported mainly from Italy (business as usual).
- This scenario will be compared with locally produced tomato paste with a 150km radius around Oxford City.
- Data for the production phases for imported tomato paste are taken from the study conducted for Emilia Romagna in Italy.
- Italy is the world's third largest producer of processed tomato products and Emilia Romagna is the biggest producer of processed tomatoes in Italy.

Assumptions/Data Collected

- The functional unit is a glass jar of single concentrate tomato paste (12-14% dry matter) with a net weight of 0.7 kg of tomato paste (1.39 kg of fresh tomato).
- The foreground inventory data have been mainly obtained from the interviews conducted in this study for the hypothetical local tomato paste data, the Emilia Romagna case in Italy for imported product, and literature review for other required data.
- The background life cycle inventory data have been largely sourced from the BUWAL 250, Ecoinvent unit processes and LCA Food DK databases.

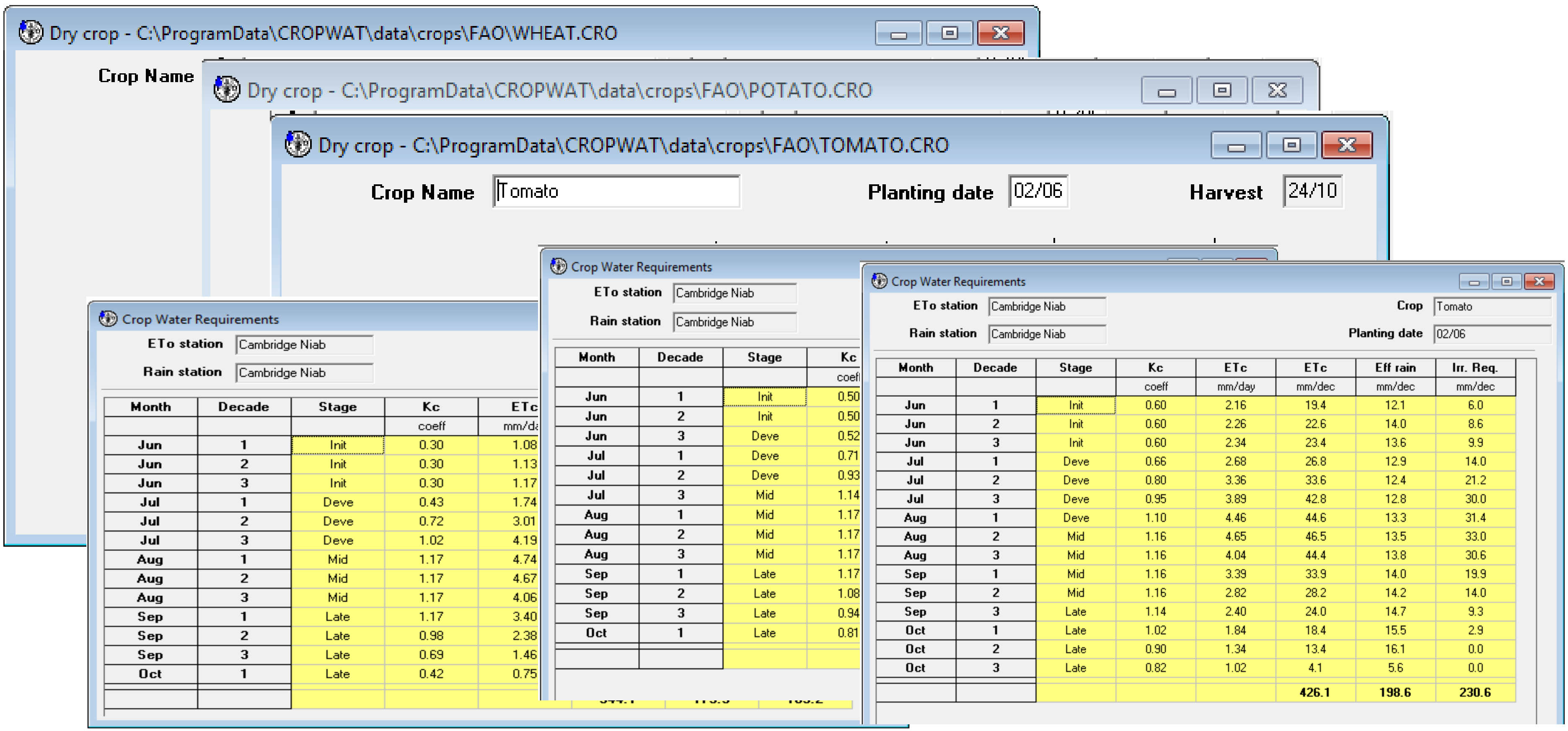
Phases of Tomato paste LCA

- **Cultivation**: open field-grown tomatoes in Emilia Romagna and heated greenhouses in the UK.
- **Manufacturing**: activities (unloading, chopping, blanching, concentrating, filling and packaging).
- **Packaging**: sourcing, production and end of life of the materials (glass bottle, tinplate, label and plastic/cardboard tray/pallet).
- **Transport**: for Imported product, all phases in Italy and imported to the UK by lorry (1620km); local product, all phases in the local area of 150km.




CROPWAT for Water Demand Estimation in Tomato Cultivation

- **Method:** **FAO Penman-Monteith** **for blue and green Water Footprint (WF) and Water Footprint Network (WFN) for estimation of grey WF.**



Month	Decade	Stage	Kc coeff	ETc mm/d…
Jun	1	Init	0.30	1.08
Jun	2	Init	0.30	1.13
Jun	3	Init	0.30	1.17
Jul	1	Deve	0.43	1.74
Jul	2	Deve	0.72	3.01
Jul	3	Deve	1.02	4.19
Aug	1	Mid	1.17	4.74
Aug	2	Mid	1.17	4.67
Aug	3	Mid	1.17	4.06
Sep	1	Late	1.17	3.40
Sep	2	Late	0.98	2.38
Sep	3	Late	0.69	1.46
Oct	1	Late	0.42	0.75

Month	Decade	Stage	Kc coeff
Jun	1	Init	0.50
Jun	2	Init	0.50
Jun	3	Deve	0.52
Jul	1	Deve	0.71
Jul	2	Deve	0.93
Jul	3	Mid	1.14
Aug	1	Mid	1.17
Aug	2	Mid	1.17
Aug	3	Mid	1.17
Sep	1	Late	1.17
Sep	2	Late	1.08
Sep	3	Late	0.94
Oct	1	Late	0.81

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Jun	1	Init	0.60	2.16	19.4	12.1	6.0
Jun	2	Init	0.60	2.26	22.6	14.0	8.6
Jun	3	Init	0.60	2.34	23.4	13.6	9.9
Jul	1	Deve	0.66	2.68	26.8	12.9	14.0
Jul	2	Deve	0.80	3.36	33.6	12.4	21.2
Jul	3	Deve	0.95	3.89	42.8	12.8	30.0
Aug	1	Deve	1.10	4.46	44.6	13.3	31.4
Aug	2	Mid	1.16	4.65	46.5	13.5	33.0
Aug	3	Mid	1.16	4.04	44.4	13.8	30.6
Sep	1	Mid	1.16	3.39	33.9	14.0	19.9
Sep	2	Mid	1.16	2.82	28.2	14.2	14.0
Sep	3	Late	1.14	2.40	24.0	14.7	9.3
Oct	1	Late	1.02	1.84	18.4	15.5	2.9
Oct	2	Late	0.90	1.34	13.4	16.1	0.0
Oct	3	Late	0.82	1.02	4.1	5.6	0.0
					426.1	198.6	230.6

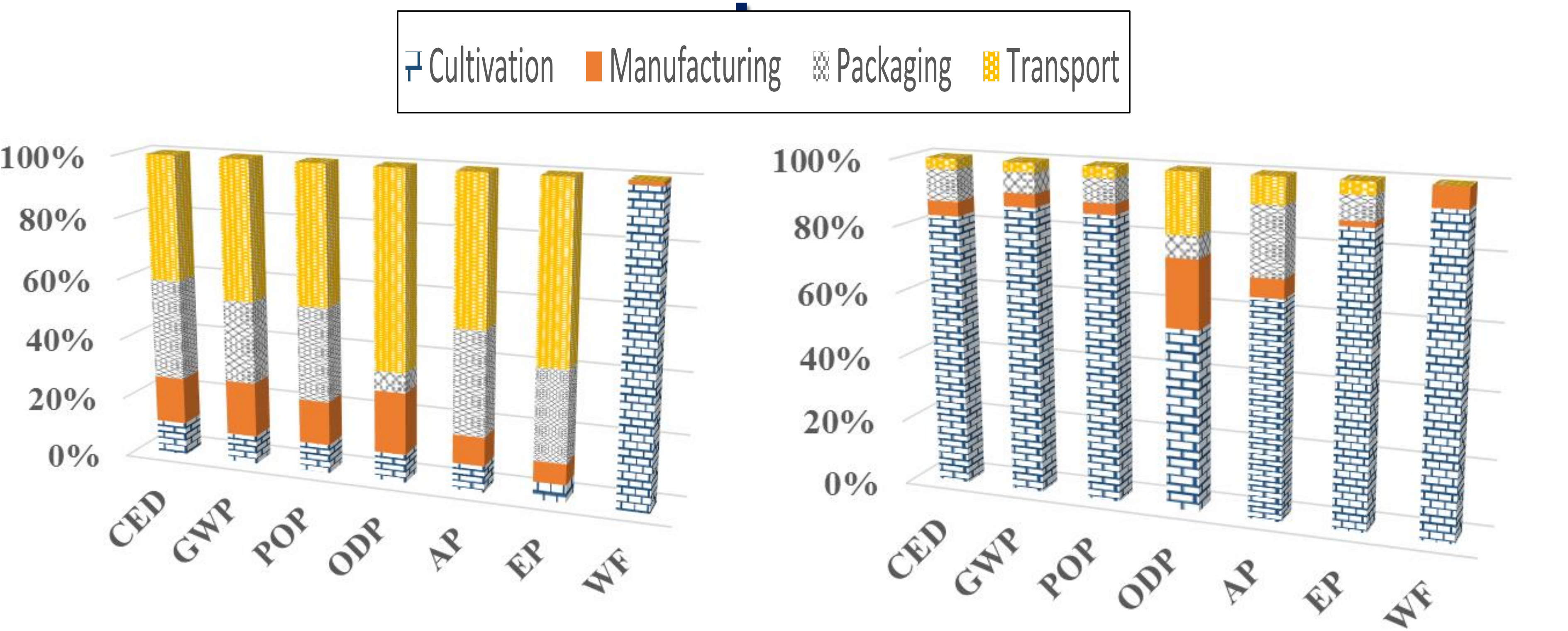
Energy/Water/Environmental Impacts for a Glass of 0.7kg Tomato Paste

- Cumulative Energy Demand (CED) used for energy footprint, CML 2001 for carbon footprint and other environmental impacts.

Impact category	Unit	Production type	Total	Cultivation	Processing	Packaging	Transport
CED	MJ-eq	Imported	13.22	1.45	2.01	4.36	5.41
		LP[1]	46.09	38.21	2.01	4.36	1.51
GWP	kg CO_2-eq	Imported	0.692	0.064	0.124	0.188	0.317
		LP[1]	3.06	2.66	0.124	0.188	0.089
POP	g C2H4-eq	Imported	0.139	0.013	0.020	0.043	0.063
		LP[1]	0.601	0.518	0.020	0.043	0.020
ODP	g CFC-11-eq	Imported	6.87E-05	6.34E-06	1.39E-05	4.43E-06	4.41E-05
		LP[1]	6.72E-05	3.67E-05	1.39E-05	4.43E-06	1.22E-05
AP	g SO_2-eq	Imported	3.806	0.328	0.353	1.294	1.831
		LP[1]	6.283	4.135	0.353	1.294	0.501
EP	g PO_4-eq	Imported	0.633	0.036	0.042	0.188	0.365
		LP[1]	2.637	2.306	0.042	0.188	0.099
WF	Litres	Imported	104.9	103.6	1.252	-	-
		LP[1]	20.56	19.31	1.252	-	-

[1]Locally produced

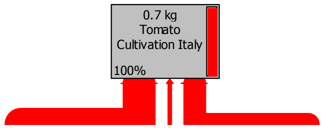
Environmental impacts
Break-down for all production



Imported tomato paste   Locally produced tomato paste

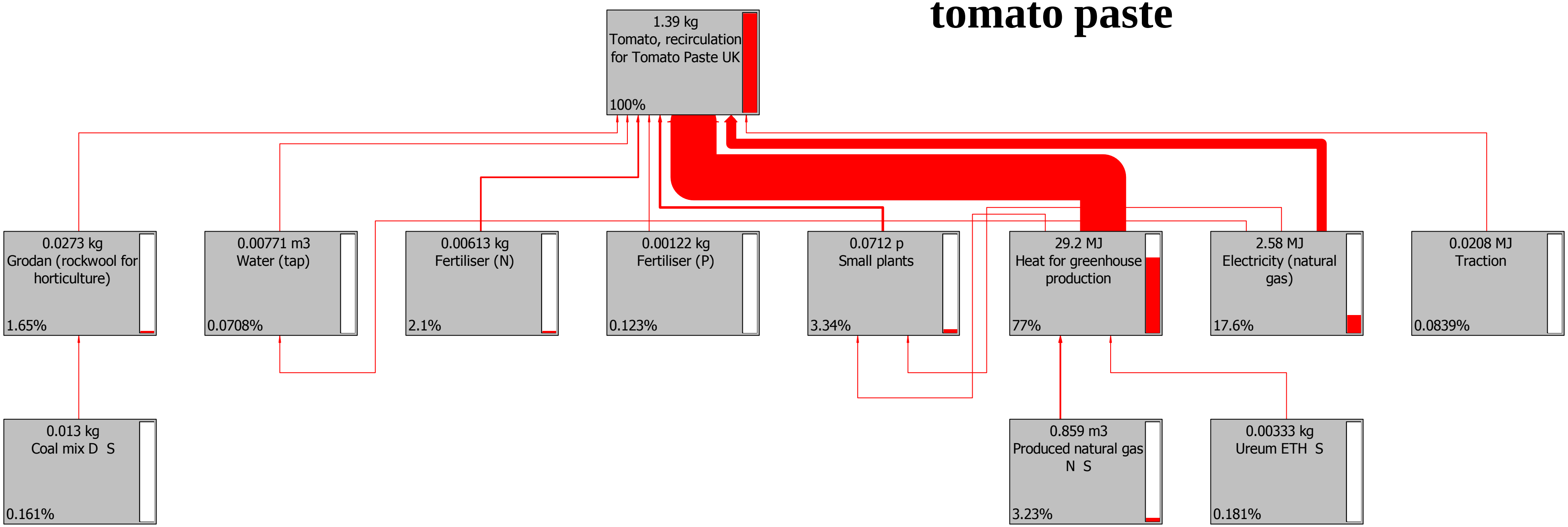
CED (Cumulative Energy Demand), GWP100(Global Warming Potential), POP(Photochemical Oxidation Potential), ODP(Ozone layer Depletion Potential), AP (Acidification Potential) and EP(Eutrophication Potential).

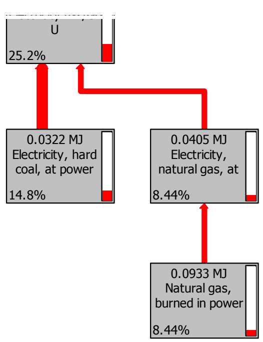
Contributing Elements of GHG emissions for Cultivation Step



Imported tomato paste

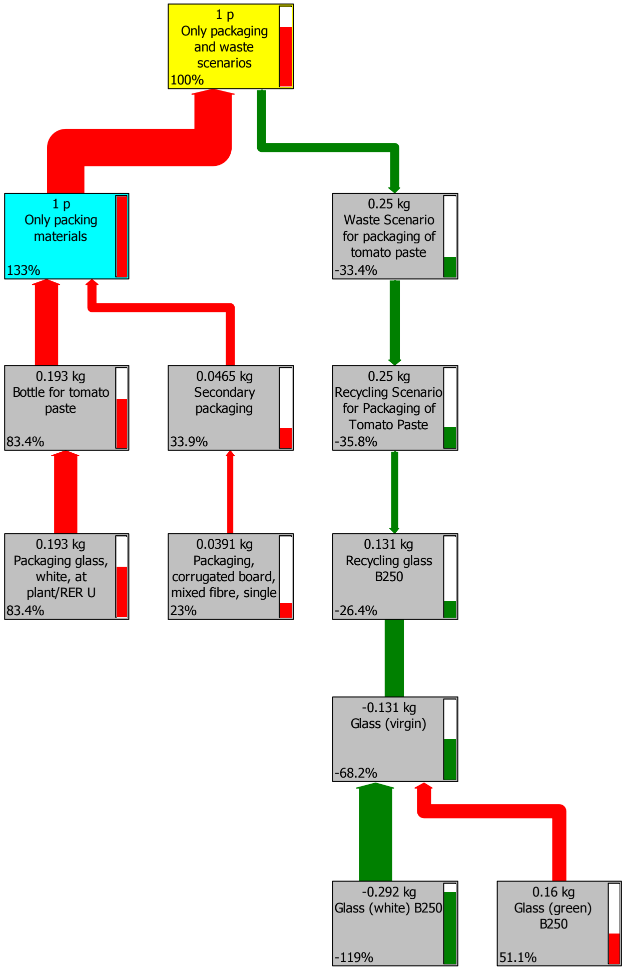
Locally produced tomato paste



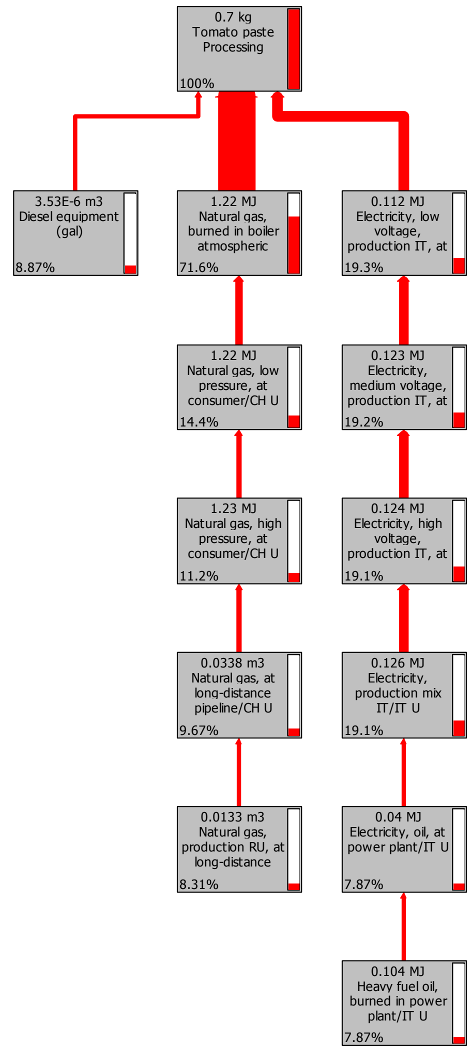


Contributing Elements of GHG emissions for Packaging/Processing Step

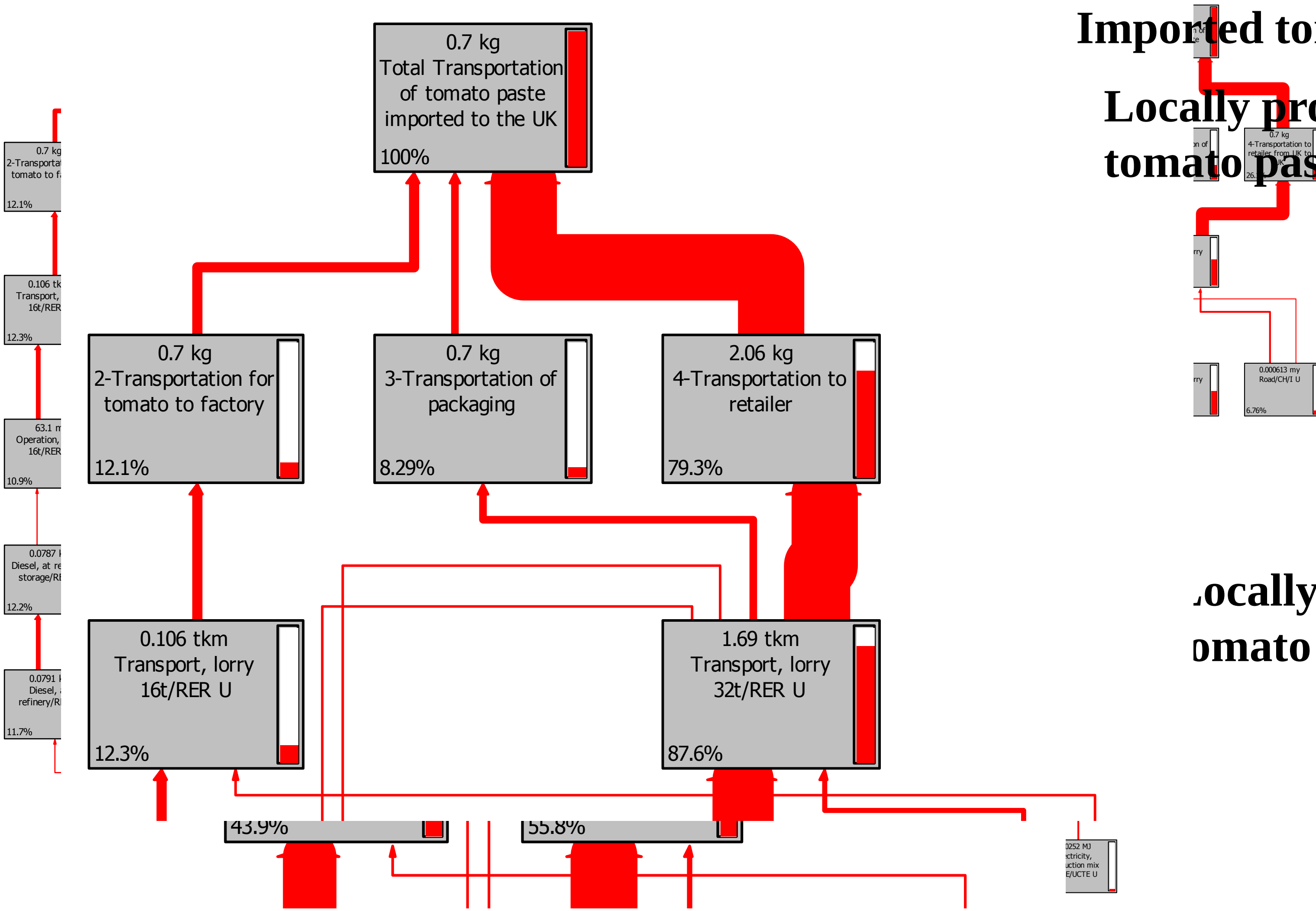
Packaging Step



Processing Step



Contributing Elements of GHG emissions for Transport Step



Imported tomato paste

Locally produced tomato paste

Locally produced tomato paste

Conclusions

- Comparison of water, energy and carbon footprints calculated for locally produced tomato paste in the UK and imported tomato paste from Italy.
- The analysis suggests that local production of tomato paste in the UK could lead to significant savings in water consumption while energy and carbon footprints would increase considerably to meet the demand for locally grown tomatoes.
- This case study is a specific example of the water-energy-food nexus and gives a good insight into the interactions between these key resources.
- As energy-carbon for heating greenhouse is bottleneck in the locally produced production, decentralised renewable sources of heating (CHP) may be considered for further investigation.

Acknowledgements

The work reported is supported by the UK Engineering & Physical Sciences Research Council (EPSRC) project Building sustainable local nexuses of food, energy and water: from smart engineering to shared prosperity (The Local Nexus Network) (EP/M017753/1).

Thanks for your attention!

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