Water in Tomato Paste

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Kourosh Behzadian, Raziye Farmani, David Butler
Centre for Water Systems, University of Exeter

Abstract
The water footprint and demand in different steps of tomato cultivation and processing are analysed in this summary. Water demand and availability and land use required for cultivation and processing are also evaluated in both case studies. Assessment of water used for tomato paste production identifies some potentials for water conservation opportunities and energy efficiency measures. These recommendations would lead to economic benefits from reduced energy costs and significant environmental benefits from the preservation of groundwater resources, lower air pollution emissions and reduced wastewater discharge and finally a great impact of water-energy nexus in food production.
Background of primary production in the UK

The first known British tomato grower was Patrick Bellow in 1554. Then, tomato was commercially cultivated in Kent and Essex in 19th century. The total amount of tomato produced in the UK in 2012 is around 84 thousand tonnes which is ranked 79 in the world in 2012 (Fig. 1). This is only less than 20% of tomato demand in the UK and the rest of demand is imported with more than 400 thousand tonnes of tomatoes per year from other countries such as Southern Spain and Italy. Given the statistics of annual tomato production in the UK between 2001 and 2012 in Fig. 2, these statistics in 2013 for the UK are 93,600 tonnes production, 410 tonne/ha yield and 224 ha area harvested.¹

Fig. 1. 10 top tomato production countries and UK in 2012²

Fig. 2. Tomato production (total area, total production and yield) in the UK between 2001 and 2012³

¹ http://faostat3.fao.org/download/Q/QC/E
² http://themissinggraph.wordpress.com
³ Department of Health, FAO, HM Revenue & Customs, DEFRA, Tomato Growers’ Association (UK), WRAP UK, HorticultureWeek.co.uk, Thanet Earth, Eric Wall Ltd, R & L Holt, Glinwell PLC, Wight Salads Group Robinson’s Nurseries, Guy and Wright, APS Salads, Canfield Food Company Ltd, British Sugar PLC
Almost all tomatoes in Britain are grown in glasshouses\(^4\). The distribution of some of the big British tomato growers is seen in Fig. 3 with associated geographical location and the area (in hectares) they grow tomatoes on. Few, if any, British tomato growers are more than 100 km from a supermarket distribution centre or wholesale market. Delivery to British supermarket shelves requires lengthy transport by road or sea. As a consequence, imported fruit can be over 7 days old before it arrives on supermarket shelves. The British Tomato Growers’ Association believes that further developing and promoting British production will benefit the environment with the consequential reduction in food miles relative to imported tomatoes. Locally and sustainably produced and locally consumed is great for the environment and great for the consumer too who can enjoy a fresher, tastier tomato\(^5\).

**Fig. 3. distribution of UK greenhouses tomato growers**

**Water footprint**

Tomatoes contain approximately up to 95% water and 5% solids/sugars (Fig. 4). Water footprint for production of 700 g tomato puree in Italy is 104.9 litres in which the cultivation phase contributes almost 99% (103.6 litres), the processing phase contributes the remaining 1% (1.3 litres)\(^6\). This indicates that water footprint of any processed tomatoes are governed by water footprint of fresh tomato. Given the percentage of tomato solids for a specific processing (e.g. paste or puree), the weight of used fresh tomato can be calculated per kg of processed product and thus associated water footprint can be calculated. For example, for making 1kg of tomato paste as ‘double concentrate’ containing 28% or 280g solid materials (called Brix), 5.6kgs of tomato with 5% solids (or 50g per kg fresh tomato) content are required. In other words, water footprint of each kg of this tomato paste is approximately equal to water footprint of 5.6kg of fresh tomato.

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\(^4\) [http://www.britishtomatoes.co.uk/environment/](http://www.britishtomatoes.co.uk/environment/)

\(^5\) [http://www.britishtomatoes.co.uk/environment/](http://www.britishtomatoes.co.uk/environment/)

Global average Water footprints for fresh tomato is 214 m$^3$/tonne. As described above, water footprint increases substantially for the processed tomato and changes from 267 m$^3$/tonne for peeled tomato to 4276 m$^3$/tonne for dried tomato (see Table 1)$^8$. The Global average water footprint for tomato paste is 855 m$^3$/tonne. In fact, the increased water footprint of processed tomato is mainly attributed to the level of concentrate applied to fresh tomato. The concept of water footprint is also categorised to three groups of blue, green and grey water. The blue water footprint refers to the volume of surface and groundwater consumed (evaporated) as a result of the production of a good; the green water footprint refers to the rainwater consumed. The grey water footprint of a product refers to the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards$^9$. The global share of these water indicators in tomato production is as follows: 52% blue water, 33% green water and 15% grey water. These rates for the UK between 1996 and 2009 are 77% for total green water including 52% through rain-fed and 25% through irrigation, 7% for blue water and 16% for grey water$^{10}$.

<table>
<thead>
<tr>
<th>Product</th>
<th>Global average Water footprint (m$^3$/tonne)</th>
<th>Green</th>
<th>Blue</th>
<th>Grey</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato fresh</td>
<td></td>
<td>108</td>
<td>63</td>
<td>43</td>
<td>214</td>
</tr>
<tr>
<td>Tomato juice unfermented &amp; not spirited</td>
<td></td>
<td>135</td>
<td>79</td>
<td>53</td>
<td>267</td>
</tr>
<tr>
<td>Tomato juice, concentrated</td>
<td></td>
<td>539</td>
<td>316</td>
<td>213</td>
<td>1069</td>
</tr>
<tr>
<td>Tomato paste</td>
<td></td>
<td>431</td>
<td>253</td>
<td>171</td>
<td>855</td>
</tr>
<tr>
<td>Tomato ketchup</td>
<td></td>
<td>270</td>
<td>158</td>
<td>107</td>
<td>534</td>
</tr>
<tr>
<td>Tomato puree</td>
<td></td>
<td>360</td>
<td>211</td>
<td>142</td>
<td>713</td>
</tr>
<tr>
<td>Peeled tomatoes</td>
<td></td>
<td>135</td>
<td>79</td>
<td>53</td>
<td>267</td>
</tr>
<tr>
<td>Tomato, dried</td>
<td></td>
<td>2157</td>
<td>1265</td>
<td>853</td>
<td>4276</td>
</tr>
</tbody>
</table>

**Water demand for primary production (growing tomato)**

Frequent light irrigation improve the size, shape, juiciness and colour of the fruit, but total solids (dry matter content) and acid content will be reduced. However, the decrease in solids will lower the fruit quality for processing. Tomatoes require water during the entire period of cultivation and for clay

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soils the optimum seasonal irrigation volume is around 120-150 mm\textsuperscript{11}. In selecting the irrigation practices, consideration must therefore be given to the type of end product required. Prolonged water deficits leads to fruit cracking. Where fruit rot is a problem, frequent sprinkler irrigation should be avoided during the period of yield formation. A good commercial yield under irrigation is 45 to 65 tons/ha fresh fruit, of which 80 to 90 percent is moisture, depending on the use of the product. The water utilization efficiency for harvested yield (Ey) for fresh tomatoes is 10 to 12 kg/m\textsuperscript{3}\textsuperscript{12}.

California produces nearly 95\% of the processing tomatoes grown in the United States\textsuperscript{13}. The average yields of processing tomatoes in California is around 90 tonnes/ha in 2004. Studies have shown that tomato yields in the salt-affected soils of California are considerably higher for drip irrigation compared to sprinkler and furrow irrigation\textsuperscript{14}.

Drip or micro-sprinkler irrigation are often used. Harvesting occurs in August and September when the fruits are fully mature, about 60-70 days after transplanting and the fruits harvested are then sent to the processing plant by truck.

Tomato is a rapidly growing crop with a growing period of 90 to 150 days. Optimum mean daily temperature for growth is 18 to 25°C with night temperatures between 10 and 20°C. Larger differences between day and night temperatures, however, adversely affect yield. The crop is very sensitive to frost. Temperatures above 25°C, when accompanied by high humidity and strong wind, result in reduced yield. Night temperatures above 20°C accompanied by high humidity and low sunshine lead to excessive vegetative growth and poor fruit production. High humidity leads to a greater incidence of pests and diseases and fruit rotting. Dry climates are therefore preferred for tomato production\textsuperscript{15}.

Water demand for processing

Tomato processed (tomato paste, puree and ketchup) is basically produced by removing the seeds, skin and pulp of tomatoes to create a tomato juice which is then thickened, normally by evaporation\textsuperscript{16}. To obtain paste and diced tomatoes or purée within a tomato process, major materials in addition to the fresh tomato include packaging containers and fresh water. Water is used for many different steps and purposes of a typical tomato processing facility. These include unloading flumes, product washing, equipment cleaning processes, heating and cooling circulation, and makeup water to cooling towers and boilers (Fig. 5).

\begin{itemize}
  \item \bibitem{12} \url{http://www.fao.org/nr/water/cropinfo_tomato.html}
  \item \bibitem{13} California Tomato Growers Association. California Tomatoes For Processing. 2005. \url{www.ctga.org/newctga/production.htm}
  \item \bibitem{14} Hanson B., May D. Drip irrigation increases tomato yields in salt-affected soil of San Joaquin Valley. Cal Ag. 2003. 57(4):7.
  \item \bibitem{15} \url{http://www.fao.org/nr/water/cropinfo_tomato.html}
  \item \bibitem{16} \url{http://www.bbpbg.com/en/category/technology-53/tomato-concentrate-puree-64#.VdSKnvVh8d}
\end{itemize}
Within the processing phase, the main components which consume water are unloading and washing (88%) and concentration and pasteurization (9%) chopping, blenching, refinement and filtration (2%) and Filling and bottle pasteurization (1%)\(^7\).

After harvesting raw tomatoes from the farm, they are transported by trucks to a plant for tomato process. A typical plant (i.e. large-scale) will receive approximately 400 trucks per day during the season. Water is used in the first stage (bulk dump) of the plant, in water flumes for washing raw tomatoes out of the truck trailers. The water used in these flumes are for the purpose of both transportation of the tomatoes to peeling/crushing area, and cleaning the tomato surfaces of excess debris (stones, insects, vines, etc.). Fresh tomatoes arriving at the plant in trucks are unloaded into a collection channel/flume, a stainless steel or cement duct into which a quantity of water 3 to 5 times higher than the amount of unloaded tomato is continuously pumped\(^8\). For example, a 10 tons/h rate requires at least 30 m\(^3\)/h of water. This water flow carries the tomatoes into the roller elevator, which then conveys them to the sorting station. The delivery trucks park-up alongside the flume and, while the trailers containing the tomatoes are being tilted towards it, an operator, using a special tube, pipes a vast quantity of water inside the truck, so that the tomatoes can flow out from the special 50 x 50cm opening. In this way the tomatoes and the water will be gradually feed into the flume without getting damaged. The tomatoes then arrive at the sorting station, after having been rinsed under a clean water spraying system (preferably drinking water).

Tomato peeling stage is usually performed by either steam or infrared. Water is used in the peeling stage as steam, which is the most common type of peeling especially in California\(^9\). Condensate in the steam systems may not be returned to the main steam boiler due to some failed steam traps and hence returning condensate is a good opportunity for water saving and water treatment costs. Infrared peeling is a non-water and non-chemical process and expected to have lower energy usage when compared to steam peeling. The Infrared peeling is also in the research and development stage, which can be a surrogate for steam peeling\(^10\).

Packaging containers used in the packaging stage are usually cleaned by hot water, steam or blasts of pressurised air\(^21\).

Finally, cooling stage can also use water for cooling after packaging stage. There are various methods for cooling such as vacuum/air cooling, surface heat exchanger, submerged cooling tower water or chilled water systems. The surface heat exchanger for a plant with a capacity of 50 tonnes/h requires around 180 m\(^3\)/h of water whereas the vacuum cooling requires around 1.4 m\(^3\)/h of water. This large flow of water would require either a liquid waste treatment system about three times larger than that provided, or else a means of recycling this water through the cooling system. While part of this


\(^8\) http://www.fenco.it/tomato-processing-lines/equipment-for-tomato-paste-production/


water flow can be recycled, its volume and temperature (40 °C) exceed that needed elsewhere in the plant\textsuperscript{22}.

Evaporation is the most energy-intensive step and is where the water is extracted, and the juice that is still only 5% solid becomes 28% to 36% concentrated tomato paste. The evaporator automatically regulates juice intake and finished concentrate output\textsuperscript{23}.

In addition to the aforementioned water saving in tomato processing, five typical water conservation measures have been recommended for water saving in different stages of tomato process (Table 2). More specifically, repair water leaks and conducting a regular maintenance program can save approximately 0.7% of water consumption. The flow from cooling water makeup water pump can be controlled by installing a level control system which can prevent overflow and eventually save up to 1.7% of water consumption. One of the main area for water saving is in the series of water flumes. Thus, the water can be recovered from the last stage of the flume and filtered and sent to former stages. This can save up to 3.8% of total water consumption. Pump/product cooling water which is usually drained can be reused in either cooling water or water flumes. This can result in water saving up to 5%. Finally, the condensate from the evaporated tomatoes can be used in cooling towers, unloading flumes and other low-grade application like washing the floor. As the water of fresh tomato is extracted (from 5% to 28-30% of solid materials) during evaporation, a massive volume of evaporated water can be condensed from this part. As a result, the total water conservation measures can result in a 15.6% facility-wide reduction of fresh water usage.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Typical_Tomato_Canning_Process.png}
\caption{Typical Tomato Canning Process\textsuperscript{24}}
\end{figure}

\textsuperscript{22} Jesse, E. V., Schultz, W. G., & Bomben, J. L. (1975). Decentralized tomato processing: plant design, costs, and economic feasibility. Agric Econ Rep Econ Res Serv US Dep Agric

\textsuperscript{23} http://www.tomatojos.net/08-tomato-paste-processing/

\textsuperscript{24}
Table 2. Typical water conservation measures and savings in tomato processing facilities

<table>
<thead>
<tr>
<th>Energy Efficiency Measure Description</th>
<th>Typical Range of Site Water Savings</th>
<th>Typical Range of Simple Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair Water Leaks</td>
<td>0.7%</td>
<td>&lt; 1 year</td>
</tr>
<tr>
<td>Prevent Overflow of Cooling Tower Water</td>
<td>1.7%</td>
<td>&lt; 1 year</td>
</tr>
<tr>
<td>Reuse Flume Water in Former Stages</td>
<td>1.1% - 3.8%</td>
<td>1 year - 4.8 years</td>
</tr>
<tr>
<td>Reuse Single Pass Cooling Water</td>
<td>1.7% - 5.0%</td>
<td>1 year - 4.8 years</td>
</tr>
<tr>
<td>Recycle Evaporator Condensate*</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

As a result, a medium scale tomato processing facilities which work 150 days in a year has a capacity of 4500 Tonnes per year and require 50 m$^3$ water per day basis. In a plant with a capacity of 50 tonnes per hour, the wash operations use about 1.1 m$^3$ of fresh water per tonne of tomatoes, or 55 m$^3$/h and with a general water demand of 90 m$^3$/h. As such, the capacity of a factory working 8 hours a day would be 400 tonnes/d of tomato paste and would take around 720 m$^3$/d.

**Water supply and quality**

Water required for tomato irrigation can be supplied from rivers, lakes, wells, boreholes, or public irrigation schemes, and is typically pumped into the field using pump system. There are different methods for tomato Irrigation such as furrow, flood, border strip, sprinkler (e.g. centre-pivot, travelling gun and drip). Sprinkler methods, through more expensive to set up, are more efficient which provide higher yield with lower water supply. In particular, drip irrigation can typically consume 50% less water and improve yields by as much as 40%.

Surface irrigation by furrow is commonly practised. Under sprinkler irrigation the occurrence of fungal diseases and possibly bacterial canker may become a major problem. Further, under sprinkler, fruit set may be reduced with an increase in fruit rotting. In the case of poor quality water, leaf burn will occur with sprinkler irrigation; this may be reduced by sprinkling at night and shifting of sprinkler lines with the direction of the prevailing wind. Due to the crops specific demands for a high soil water content achieved without leaf wetting, trickle or drip irrigation has been successfully applied.

Water obtained from raw water resources (e.g. groundwater) needs to properly be treated. Sometimes it is treated by sand water filtration but it can be further filtered using Reverse Osmosis (RO) systems if high quality water is required for usage in boilers and pump operation. The non-RO fresh water is usually used for the tomato unloading flumes, the single pass cooling systems and to wash and clean surfaces and equipment.

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27 National Canners Association, Liquid Wastes from Canning and Freezing Fruits and Vegetables, Water Pollution Control Series, 12060 EBK 08/71 (1971)
28 http://www.tomatojos.net/irrigation-practices-in-west-africa/
29 http://www.fao.org/nr/water/cropinfo_tomato.html
The water flow through this wash system is counter current, with potable water entering at the final rinse. The wash water is chlorinated to 5 to 10 ppm to maintain sterility\(^{31}\). Water cooling involves agitating the cans for about 2 h under a spray of atomized water that has been chlorinated to 15 ppm residual chlorine\(^{32}\).

Estimates of wastewater production per tonne of tomatoes processed range from 1.5 to 7.5 cubic metres\(^{33}\) and most of this wastewater comes from raw product fluming, washing, and peeling stages.

**Water availability**

The Environment Agency is responsible for managing water resources in England\(^{34}\). Water abstraction more than 20 cubic metres a day from either a surface source (such as river, stream or canal) or an underground source needs an abstraction licence from the Environment Agency although some cases such as trickle irrigation are exempted from applying for licence\(^{35}\). The availability of water resources for abstraction is assessed by the Environment Agency through the Catchment Abstraction Management Strategy (CAMS) approach. The CAMS determines the amount of water is potentially available for further abstraction based on the amount of water already licensed for abstraction and the extent for the environment needs. The Environment Agency uses four colours known as CAMS resource availability colours to indicate the amount of water available for additional abstraction (blue: high hydrological regime; green: water available for licensing; red: Water not available for licensing; grey: Heavily Modified Water Bodies and /or discharge rich water bodies). The Environment Agency also accepts water abstraction for licence holders at four different flows including low flow (Q95); below moderate flows (Q70); moderate flows (Q50); and higher flows (Q30). For example, low flow (Q95) is the flow that is exceeded 95 percent of the time of specific surface flow. As such, for lower flow, permission for water abstraction would be stricter as there is less water available to be provided for consumers (Fig. 7).

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\(^{34}\) https://www.gov.uk/government/collections/water-abstraction-licensing-strategies-cams-process  
\(^{35}\) https://www.gov.uk/guidance/water-management-abstract-or-impound-water
Fig. 7 Abstraction permissions at moderate flows (Q95) and high flows (Q30) in the England and Wales.

The Environment Agency uses CAMS approach based on 16 different map areas in the UK for water abstraction licence. Most areas in Oxfordshire are grouped in the three drainage catchments of West Thames map area including 1- Cherwell, Thame and Wye catchment (i.e. Oxford city and the northern and eastern parts of the county), 2- Kennet and Vale of White Horse Catchment (i.e. southern parts of the county) and 3- Cotswolds Catchment (i.e. western part of the county).

The Cherwell, Thame and Wye catchment (Fig. 8) covers an area of approximately 2200 square kilometres and is predominately rural in character and is used extensively for agriculture, such as arable crops and grazing. In Kennet and Vale of White Horse Catchment, southwest is a semi-rural landscape, with the Marlborough Downs characterised by arable farming, horse gallops and permanent chalk grassland. To the north of the area is a predominantly arable and grassland

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landscape stretching between Swindon and Oxford. The Cotswolds CAMS covers an area of about 1700 km², lying largely within Gloucestershire to the west and Oxfordshire to the east. The area is dominated by the Cotswold Hills and is largely rural, with many picturesque small towns and villages. The predominant land use is agricultural with about half of the total area used for arable farming, a further third is grassland and the remainder woodland and small urban areas.

Most of the areas in the catchment will not be granted at low flow and water is only available during periods of high flow. Consumptive groundwater licences, which do not have a direct impact and immediate impact on river flow, may be permitted all year, providing the level of resource use allows, but may have restrictions such as prescribed groundwater level. Similar situation is in place for Northstowe area and associated permission for water abstraction. As the water demand for tomato paste factory for our case studies use less than 20 m³/d, no serious issue will arise for this part. However, this could be limiting factor for the size of glasshouse created for tomato cultivation. More specifically, given the irrigation water demand for tomato in Oxford and Northstowe is between 0.1 and 0.35 L/s/ha, this would take water demand between 8.6 and 30 m³/d per hectare. Therefore, in cases of high water demand (i.e. big area for glasshouse), glasshouse should be located in an area in which permission for groundwater abstraction is allowed.

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41 Calculated water demand for tomato cultivation based on CROPWAT tool
Potentials for water-energy-carbon nexus in tomato paste production

There are some potentials for water-energy and even carbon nexus in various steps of tomato paste including primary production and processing. Primary production which is done in glasshouses in the UK use significant energy and have some specific impacts on environment. Although it is used fossil fuel to heat glasshouses, there are some benefits in this kind of tomato production such as almost complete elimination of pesticide use, major reductions and major reduction in GHG emissions, acidification and eutrophication due to less use of fertilisers and hence associated fugitive emissions of methane, ammonia and nitrous oxide. To heat glasshouses, the majority of the tomato production area in the UK currently use natural gas and thereby reducing sulphur emissions which would come from burning oil or coal. To improve the production quality and amount, glasshouse atmosphere can uptake CO2 extracted from burning gas and thus result in further reduction in GHG emission.

Some of the tomato growers in the UK employ advanced bio-technology to grow tomato in which the minimum carbon and water footprints are created. For example, Guy and Write factory produces eco tomato with heat generated from Biofuel and use CO2 emissions from the Micro Turbines within the glasshouse for enhancement of tomato growth. One of the most exciting technical opportunities for the UK tomato industry is to use Combined Heat and Power (CHP) in which electricity generating stations are situated in tomato nurseries. Tomato crops in glasshouse use heat and CO2 generated by surplus energy from industrial processes. A good example of this is British Sugar factory which exports electricity for 160,000 homes using CHP plants and uses the combustion gases to grow around 140 million ‘eco-friendly’ tomatoes at Cornerways tomato Nursery. In this tomato Nursery, hot water is carried through piping from the nearby factory’s CHP plant to maintain the balmy temperatures which suit tomato plants around the glasshouse. The heat in the hot water would otherwise be removed using cooling towers. This nursery would benefit from carbon dioxide (a by-product from the CHP boiler in the sugar factory) by its pump into glasshouse to be absorbed by the plants during photosynthesis rather than vented into the atmosphere as waste emissions. It is estimated that over half of the UK tomato production area is now equipped with CHP facilities. CO2 uptake by British tomato crops is estimated to be 20-25,000 tonnes per year.

Likewise, if tomato paste factory is built in the nearby tomato farm, the surplus evaporated water and its condensation and water recycled from cooling step can be used for warming up the glasshouses or for irrigation of tomato growing in the glasshouse. The surplus water used in the tomato processing would otherwise be wasted into drainage systems as it may not be used for other processing stages in the factory.

Water recirculation systems is used by a number of tomato growers in the UK. The plant roots are bathed in water which then drain into tanks before being checked, adjusted and reused. Glasshouses now being built for tomato production have the facility for water and nutrient recirculation. A new type of anaerobic digestion (AD) system can also be used in the primary production to convert

42 http://www.guyandwright.com/tomatoes.php
43 http://www.britishsugar.co.uk/About-us.aspx
organic waste from tomato production into energy, CO2 and other products, including biodegradable packaging 44.

Currently on the main strategies of British tomato association is to continuously investigate on alternative and renewable energy (e.g. waste heat from other industries) and water saving usage without compromising plant health and fruit quality 45. Some good promising water saving strategies are to develop purification systems for safe reuse of waste and rainwater supplies. In the Cornerways tomato Nursery, the rainwater from the glasshouse roof is harvested as much as over 115 million litres annually for tomato growth irrigation 46.

**Water demand for local tomato paste in case studies**

**Oxford**

Based on the estimation of minimum capacity for a small tomato paste factory in/near Oxford (2,000 tonnes), some 12,000 tonnes of fresh tomatoes are required to be cultivated (around 14% of UK current tomato production) 47. Given the global water footprint of 214 m³/tonne for fresh tomato, the water demand for tomato cultivation in Oxford would be 25.7 million m³ per year. Assuming the daily capacity of tomato paste production is 20 tonnes/d (100 working days) and given that tomato paste production of 400 tonnes/d requires 720 m³/d, water required for tomato paste would be around 3,600 m³ per year. As such, given the product yield of tomato in the glasshouses in the UK (407 tonnes/ha in 2012) 48, the total land area required for tomato cultivation would be around 29.5 ha of glasshouses.

**Northstowe**

Northstowe when complete within three phases will have up to 10,000 new homes and a population of around 24,400 people is anticipated to live in the new town 49. The layout of the Northstowe planning and three planning phases are shown in Fig. 9.

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44 [http://www.britishtomatoes.co.uk/meet-the-grower/4/](http://www.britishtomatoes.co.uk/meet-the-grower/4/)
45 [http://www.britishtomatoes.co.uk/uploads/media/628572ebc288df9750da49a22fd81d2f6f07c0fa.pdf](http://www.britishtomatoes.co.uk/uploads/media/628572ebc288df9750da49a22fd81d2f6f07c0fa.pdf)
46 [http://www.britishsugar.co.uk/tomatoes.aspx](http://www.britishsugar.co.uk/tomatoes.aspx)
47 Julian Cottee, Initial Research Summary of Tomato Paste, Local Nexus Network of food, energy and water, Oxford University, 2015
Fig. 9 New development of Northstowe (a) overall layout in the region (b) the three planning phases\(^5\)

Similar to the calculation in Oxford, Northstowe with the population of 24,000 inhabitants (15% population size of Oxford) would require only 20 tonnes of tomato paste for domestic and catering businesses annually. As the minimum capacity of a tomato paste factory producing 2000 tonnes of tomato paste, this would turn out to be a factory with more than 100 times as much as Northstowe consumes (This magnitude rate was 15 times in Oxford case study\(^5\)). Given the total area of 483ha land in all phases, the percentage share across the site is shown in Table 3 for all phases in the Northstowe masterplan.

<table>
<thead>
<tr>
<th>Land use</th>
<th>Phase 1 (Ha)</th>
<th>Further phases (Ha)</th>
<th>Reserved land (Ha)</th>
<th>Total (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site area</td>
<td>97</td>
<td>331</td>
<td>54</td>
<td>483</td>
</tr>
<tr>
<td>Residential</td>
<td>43</td>
<td>149</td>
<td>28</td>
<td>220</td>
</tr>
<tr>
<td>Local centre</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Town centre</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Employment</td>
<td>5</td>
<td>11</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Primary schools</td>
<td>3</td>
<td>11</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>Secondary school</td>
<td>0</td>
<td>12</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Sports hubs</td>
<td>6</td>
<td>26</td>
<td>4</td>
<td>36</td>
</tr>
<tr>
<td>public open space</td>
<td>28</td>
<td>91</td>
<td>19</td>
<td>138</td>
</tr>
<tr>
<td>Allotments</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Busway</td>
<td>1</td>
<td>7</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Primary streets</td>
<td>5</td>
<td>14</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>Plot roads</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

\(^{50}\) HCA (Homes & Communities Agency) 2014. Design and Access Statement, NORTHSTOWE Phase 2 Planning Application.

\(^{51}\) Julian Cottee, Initial Research Summary of Tomato Paste, Local Nexus Network of food, energy and water, Oxford University, 2015

\(^{52}\) HCA (Homes & Communities Agency) 2014. Design and Access Statement, NORTHSTOWE Phase 2 Planning Application.
As reported in the published documents of Northstowe, there is no industry including processing and manufacturing inside the urban development. However, there are some areas of land allocated for public open spaces, allotments and community orchard (total of 140 ha) and thus part of it can be potentially considered for product cultivation (i.e. growing tomato) although this needs to be negotiated with associated stakeholders. As the ratio of fresh tomato required to produce double concentrate tonne paste is 6:1, 120 tonnes of fresh tomato are needed for 20 tonnes of tomato paste in Northstowe consume. Given the tomato yield of 407 tonnes/ha in the glasshouses in the UK, around 0.3 ha of glasshouses in Northstowe can be used for tomato glasshouses. As such, such a glasshouse would take 25.7 thousands m³ water annually for cultivation of tomato in Northstowe. The main challenge here would remain to see if such a small-scale tomato paste factory with the capacity of only 20 tonnes annually would exist. For such a small-scale factory if available, the water demand is negligible which can be even supplied from mains water. Otherwise, a minimum scale of tomato paste factory which can be built in Northstowe should be taken into account and the extra tomato paste production can be consumed for other nearby areas.

Summary and Conclusions

According to the need for proximity of tomato paste factory and primary production, background of tomato cultivation was reviewed in the UK where 80% of tomatoes are imported and all cultivated tomatoes are grown in heated glasshouses. The analysis of water demands for tomato cultivation and processing shows 99% of water are used for primary production although there are still some opportunities for water saving especially in processing. This would lead to potentials of water-energy nexus in tomato paste production and their connection to carbon footprint in both stages. The followings are also some key points which can be suggested for further analysis and investigation:

- Based on the survey in the public reports and documents for Northstowe case study, no manufacturing area was observed inside the boundary of the new development and probably this would need to be considered somewhere in the nearby areas. This probably needs to be discussed in further details with stakeholders and urban designers.
- Although water demands for producing tomato paste in the scale of the two case studies can be supplied in some areas of the case studies, possibly one the main challenges for feasibility of tomato paste production at this stage is to identify a cost-effective small-scale technology. Probably, the interview with tomato growers and manufacturers can better clarify some of the questions and ambiguities raised here.
- As the scale of tomato paste demands for the two case studies are too small, one of the remedy for resolving small-scale technology might be to expand the scale of demands to the county of both case studies as long as water demand can be provided without any major serious. Even if water demand is an issue for a larger scale, the primary focus could be on tomato paste plants which substantially consume smaller amount of water than primary production.