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The effect of increased water prices on the Australian construction industry

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ABSTRACT: This paper evaluates the effect of increased water prices to the wider economy on the Australian construction industry. This research explores the uncertain effects of future water policy on the construction industry by depicting the consequences of possible scenarios. The effect increased water prices on the cost of construction was determined by initially calculating the embodied water of eight residential case studies. An input-output based hybrid embodied water analysis was undertaken. A range of water pricing scenarios was then applied to the case studies. It was found that despite the considerable amount of water embodied in construction, increased water prices would impact minimally on the cost of construction. This is primarily because water costs are initially such as small proportion of total building price that even quite large price increases have a minimal effect. Extremely large price increases were found to have an impact on construction price, but it is not envisaged that such prices will be applied in the foreseeable future, unless rainfall predicted reductions in rainfall from the enhanced greenhouse effect happen almost immediately. Although this appears to be a near-neutral result for economic activity, the environmental impact of development in terms of embodied water are considerable.

Conference theme: Construction and materials
Keywords: Environmental policy, water prices, construction, residential

1. INTRODUCTION
Population increase and subsequent urbanization, industrialization and development is putting a growing strain on water resources. This is having adverse social and environmental impacts. Besides these issues, many economies are beginning to suffer the effects of a limited water supply. Incongruously, Australia is both the driest inhabited continent and one of the world’s largest consumers of water per capita. The industrialized economy requires water to some degree for all production processes. However prices do not reflect the scarcity of water, particularly relatively between domestic consumption and industry. This has created inefficient and excessive consumption with little incentive to conserve resources. If water is valued appropriately, an efficient reallocation may occur. A direct price increase is one means of achieving this. Price rises may be the result of general increases or the implementation of specific economic instruments such as taxes or trading permits. The effect of increased water prices on the economy will vary. Industries, companies and projects with water intensive practices and materials will incur the greatest burden. As a result, there is a lack of industry support for such a strategy. This probably stems from concerns about economic growth and industry competitiveness. The construction industry consumes large amounts of water, indirectly through consumption of goods and services. However, little is known about the potential sensitivity of construction price to water prices elsewhere in the economy. Therefore, the aim of this research is to investigate the effect a range of potential increases in water prices may have on construction prices.

2. BACKGROUND
In 2000-01 the amount of surface water and ground water available for use was 40 teralitres, ie. 10¹² litres, or TL (NHT, 2002). 63% of this, or a total of 25 TL, was consumed in the Australian economy (ABS, 2004). As a result, over 30% of supply systems were over-committed in water allocation or at their extraction limit (NHT, 2002). Australia is the third largest consumer of water, consuming 1.3 megalitres, ie. 10⁸ litres, or ML, per capita per year (OECD, 2001). This comprises direct and indirect water consumption, i.e. not just the average amount of water consumed directly but also including the water consumed in the manufacture of other goods and services that we consume (calculated by taking total water consumption for all activities and dividing by the population). Total consumption increased by 65% from 1985-86 and 1996-97. Although the increments slowed, there was a further increase by 12% from 1996-97 to 2000-01. Besides agriculture, industry combined consumes the greatest amount of water in the Australian economy. The household sector consumes the majority of the remainder. Australian water prices are amongst the lowest in the developed world (OEDE, 2005). Prices differ across the economy with major variance between the cost of water to households, industry and agriculture. Pricing also differs between urban and rural areas. The economy and the environment are inextricably linked through the input of environmental resources to the economy to sustain economic activity (Costanza et al., 1997). The production of commodities requires natural resources and transforms these from discovery, extraction and refinement into useful raw materials which are inputs into economic goods and services (Van den Bergh and Nijkamp, 2000). As a result, economic markets play an important role in the sustainability of natural resources. Sustainable development can be described with reference to
Environmental taxes can be consumption taxes, based on the quantity of tax base taken from the environment or product taxes, increasing the cost of products that consume the tax base during their manufacture and construction (Barde, 2000). A tax on groundwater extraction is an example of a consumption tax. A tax on the embodied water of materials is an example of a product tax. In both examples the tax is passed through the producer onto the consumer resulting in increased costs. With regard to the building industry, a construction company may be charged a price per kL of water extracted, or a purchaser of a building may pay a price for the amount of water consumed in the building. Both the construction company and the purchaser can react to the price increase by choosing to reduce consumption with the use of different materials and processes or buying a building with lower embodied water. A water tax creates efficient consumption from the reduction methods undertaken by industry, industry structure and consumer decisions (OECD, 2001). Taxes create these efficiencies with their impact on relative prices. Increased production costs are reflected in higher prices on products and activities that consume large amounts of water. Consumers choose lower priced alternatives that are less environmentally damaging (OECD, 2001). Apart from this initial efficiency increase there is a continued incentive to increase efficiency. Industries are generally resistant towards environmental taxation. This is because companies that are subject to environmental policy instruments only pay reduction costs, not also the tax on the remaining consumption. A tax encourages continued reduction of consumption when reduction costs decline.

The embodied water of a product is the water needed to create and deliver a product through all stages of production, containing both direct and indirect paths for all materials and resources used to produce that product. Direct water is the water consumed in the main production of the specific product been analysed. It is easily assessed because it is a single source of consumption. Indirect water is the water used to create and deliver materials and resources that go into the main product. Studies of water embodied in construction are rare (Lenzen and Foran, 2001; Tilroy and Crawford, 2004). It is harder to define because of the many sources of consumption that may be involved, thus methodology is critical.

3. METHOD

There are a number of methods that can be used for embodied water analysis, the accuracy and extent of analysis depends on the method chosen. The methods can be classified into three separate groups, process analysis, input-output analysis and hybrid analysis (Bullard et al., 1978). Crawford presents an analysis of available methods, and finds greatest balance of reliability and completeness in the input-output-based hybrid analysis method developed by Treloar (1997). Direct inputs to a specific product or process at the focus of the analysis are calculated using process data. The process values are substituted into the input-output model for the equivalent input-output values without changing any of the upstream processes or truncating the system boundary. Other processes considered important have process data collected and substituted into the input-output model. To maximize completeness, further upstream processes are accounted for using input-output data. The method of this research can be broken into two main steps; under these steps are a number of sub-steps. First the embodied water of case studies is calculated. Then with the aid of scenario analysis this information is then used to evaluate the effect increased water prices would have on each case study.

3.1. Step One - Embodied water analysis

An analysis of the effect of increased water prices on products must consider the increased cost of water consumed directly and the increased cost of water consumed to produce other materials that are inputs to the main process. Input-output-based hybrid analysis allows the indirect effects to be calculated while accurately calculating the direct effects to evaluate the accumulated effects of increased water costs. Therefore input-output-based hybrid analysis is used to calculate the embodied water of case studies. The description of the method applied is adapted from Crawford (2004; 2005). The method can be separated into four sub-steps. These steps describe the individual analysis methods used in the hybrid approach.

The first step is to calculate the embodied water with standard input-output analysis. Input-output tables are organized into sectors of the economy. Each sector has a direct water intensity and a total water intensity recorded in kL/$1000. The direct water intensity is the water consumed directly for $1000 of output. The total water intensity is the total amount of water consumed including all direct and indirect inputs in $1000 of output. The ‘residential building’ sector is used for the case studies. The total water intensity of the sector is multiplied by the price of each case study $ x kL/$1000 then divided by 1000 to correct the units. These methods and data sources have been detailed elsewhere in Tilroy and Crawford (2004) and Lenzen and Treloar (2004).
The second step is to use process data to calculate the embodied water of the main materials. The water paths for each individual case study are modified using material quantities and direct water intensity. Each case study is broken up into elements, the elements are broken up into items with corresponding materials making up the items, measured quantities of the materials in the items that make up the element and the unit used to measure the quantity. The process based material intensities are multiplied by the material quantities to calculate the embodied water of each material input.

The third step uses process-based hybrid analysis to derive hybrid water intensities that are multiplied by individual quantities obtained from the process analysis to calculate the embodied water of individual materials. Hybrid water intensities are calculated for the basic materials obtained from the process analysis. This allows a calculation of the material inputs to each case study. The hybrid water intensity for each material is calculated by adding the material process water intensity from the process analysis and the adjusted input-output water intensity, this is the input-output derived total water intensity of the sector minus the total water intensity of the input-output path of the material being analysed. This figure is then multiplied by the price of the material and divided by 1000 to correct the units. The hybrid material water intensities then replace the process based material water intensities and are used to determine the embodied water of each material based on the quantities and method used in the process analysis. The revised individual material water intensities are multiplied by the material quantities to calculate the embodied water of each material. The direct water of each case study is then calculated using input-output data. The direct water intensity obtained from the initial input-output analysis in step one is multiplied by the price of each case study $x$ kL/$1000 then divided by 1000 to obtain the water consumed directly in each case study.

The final step combines the information obtained from the previous stages. The algorithm developed by Treloar (1997) is used to systematically extract pertinent water paths for each case study. The inputs quantified from the process analysis are assigned to specific input-output paths. The total water intensity of the paths for the process inputs is then deducted from the total water intensity of the sector. To avoid double counting, the process value where available is subtracted from the total water intensity of the sector. The remaining paths are multiplied by the price of the case study and divided by 1000 to correct the units and calculate the additional embodied water of each case study. Finally, the process-based hybrid analysis embodied water value obtained in step three is then added and the direct water component is subtracted as this is already included. The resulting figure is the input-output-based hybrid analysis embodied water figure for each case study.

3.2. Step two – Scenario analysis
The impact increased water prices would have on construction is calculated with scenario analysis. Three different tax rates are developed along with a baseline scenario, assuming no taxation. Using business as usual building prices the significance of change as a result of each scenario is measured relative to the baseline. The results obtained from the input-output-based hybrid analysis provide the basis for the evaluation of the effect of increased water prices on construction. The tax rates are multiplied by the embodied water of each case study to estimate the cost to construction as a result of each scenario. The baseline scenario is a business as usual model and assumes no policy intervention. It is the cost of construction without the increased costs of water. To relate to the 1996-97 input-output data and process data used in the embodied water analysis, the baseline scenario is developed from 1997 data. The total costs are calculated with 1997 national pricing handbooks (Rawlinsons, 1997). The handbooks have different classifications of buildings. Each case study is classified under the handbook guidelines. The floor area of each case study is multiplied by the appropriate rate for the buildings classification then adjusted for individual characteristics that have a large impact on price. The classification used in the total costing is used to calculate the elemental cost of construction. The handbooks provide a rate for elements per square metre and as a percentage of total building costs. The elemental costs as a percentage of total building costs are used to calculate their price.

A 1997 industry average figure per kL for the cost of direct onsite water consumption is used to measure the baseline cost of the water directly used for the onsite construction process. The figure is $0.68 per kL. This is the average cost of delivery for 16 water service providers in Australia. The data was compiled from the Water Services Association of Australia publication WSSA Facts (1998), which presents information from the previous year. Three different taxation scenarios are developed to analyze their effect on construction. The taxation scenarios are based on overseas examples and have been adapted to account for Australian conditions. All proposals are a broad-based one price tax on the consumption of water by the economy. The first taxation scenario, partly based on the Netherlands water supply tax, is considered low. The rate used is $0.22 per kL of water supplied to the economy. The second taxation scenario, partly based on Denmark’s tax on water quantity, is considered moderate. The rate used is $0.95 per kL of water supplied to the economy. These two rates have been adjusted to account for the purchasing price disparity between the countries, this result's in a smaller rate of taxation than the original models in both instances. The third taxation scenario is based on the notion of levels continually dropping, creating a need to raise price incentives to increase consumer awareness. The rate used is $5.00 per kL of water supplied to the economy.

The construction industry has a direct tax burden based on the water it directly consumes and an additional indirect tax burden on the water consumed to produce its inputs. These inputs are produced with other inputs and so on. The analysis method allows the infinite series of indirect inputs to be calculated to evaluate the accumulated effect of a water tax on the construction industry. To measure the total effect on construction from each tax scenario the direct and indirect burden must be calculated and then summed. The indirect effect on construction is calculated by multiplying the embodied water of buildings in kL by the tax rates in each scenario. The water consumed directly calculated in the embodied water analysis is then multiplied by the tax scenarios. The additional direct and indirect figures are then added together. This is the total effect on construction resulting from each taxation scenario.
3.3. Case Studies

There are many different buildings in the built environment. These range from simple residential construction, such as single and double brick or weather board housing to non-residential construction, such as high-rise and industrial developments. This research focuses on residential buildings. Residential buildings account for approximately two thirds of the value of work produced by the construction industry in Australia. Eight case studies have been selected for this research. The case studies range from solid brick and brick veneer houses to weatherboard homes. The case studies were chosen specifically to represent suburban residential housing in Australia. The dwellings have a building area ranging from 82 to 156 m$^2$. These are quite small, by common standards today, but represent a lot of inner urban developments. Extrapolations can be made fairly reliably to larger buildings on a square metre basis, based on experience. Standard pine timber frames with concrete ground floor slabs or timber floor joists on stumps are used. Buildings with second floors have timber floor joists supporting the second level. Roofs are conventional pitched or flat roof construction or trussed. The buildings are well insulated with fibreglass insulation both in the roof and walls.

<table>
<thead>
<tr>
<th>RCS Case Studies</th>
<th>Description</th>
<th>Area (m$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCS 1</td>
<td>Semi detached 2 storey</td>
<td>126</td>
</tr>
<tr>
<td>RCS 2</td>
<td>Attached 2 storey</td>
<td>82</td>
</tr>
<tr>
<td>RCS 3</td>
<td>Semi detached 2 storey</td>
<td>82</td>
</tr>
<tr>
<td>RCS 4</td>
<td>Attached 2 storey</td>
<td>156</td>
</tr>
<tr>
<td>RCS 5</td>
<td>Detached 2 storey</td>
<td>155</td>
</tr>
<tr>
<td>RCS 6</td>
<td>Detached single storey</td>
<td>151</td>
</tr>
<tr>
<td>RCS 7</td>
<td>Semi detached single storey</td>
<td>100</td>
</tr>
<tr>
<td>RCS 8</td>
<td>Attached 2 storey</td>
<td>112</td>
</tr>
</tbody>
</table>

4. RESULTS

Figure 1 presents the results of applying each taxation scenario to the case studies. The low, moderate and high rates of taxation increased building costs by an average of 0.5%, 2.3% and 11.5%. The average building costs were $710/m$^2$. This results in an average increase in costs by $3.62/m$^2, $15.65/m$^2 and $82.38/m$^2. RCS 3 has the highest percentage increase in costs ranging from 0.7% to 3.1% to 16.7%. RCS 3 also has the highest actual increase in costs ranging from $4.05/m$^2 to $17.49/m$^2 to $92.10/m$^2. RCS 3 has the highest embodied water (18.42 kL/m$^2$) with the equal lowest building costs ($550/m$^2). RCS 4 has the lowest percentage increase in costs ranging from 0.3% to 1.4% to 7.4%. RCS 4 also has the lowest actual increase in costs ranging from $3.07/m$^2 to $13.28/m$^2 to $69.90/m$^2. RCS 4 has the lowest embodied water (13.98 kL/m$^2$) with the highest building costs ($940/m$^2).
$2.87/m^2$. The fixtures and fitments group has the second lowest embodied water (0.57 kL/m$^2$) with the third lowest building costs ($65.49/m^2$), representing 9.2% of total cost.

The structure group has the highest actual increase in costs ranging from $0.71/m^2$ to $3.06/m^2$ to $16.12/m^2$. The structure group has the second lowest percentage increase in costs ranging from 0.3% to 1.4% to 7.0%. The structure group has the highest embodied water (3.22 kL/m$^2$) with the fourth highest building costs ($231.87/m^2$), representing 32.6% of total costs.

5. DISCUSSION
The taxation scenarios were developed with reference to overseas examples. The scenarios were simplified proposals and should be treated as illustrations of major changes required to the structure of water pricing. They do not represent the complex and more nuanced proposals that are likely to be developed from the balancing of environmental interests and economical needs by the lawmaking process (Hoerner, 2000). Price changes as a result of a water tax are unlikely to be uniform like the GST. One or a number of tax bases usually with different rates will levy a tax. A tax on water could have different tax bases for, regulated or unregulated water, surface or ground water, mains or self-extracted water. Currently water prices vary considerably across sectors of the economy. However, to measure the effect of a water tax, as is common in energy taxation analysis, the law of one price has been applied. All scenarios were broad-based one price taxes on the consumption of water by the economy. This assumption simplifies the analysis considerably. It has been assumed that the water tax burden is passed entirely on to the end consumer in the form of increased prices of goods and services. This is the most common assumption in academic literature (Hoerner, 2000).

Case studies with a large gap between high embodied water and low building costs were most affected by increased water prices. The percentage increase in costs rose significantly compared to case studies with a large gap between low embodied water and high building costs. Despite the percentage increase in costs being significant on many of the case studies with a large gap between high embodied water and low building costs, the actual increase in costs was less than case studies with a smaller gap between high embodied water and low building costs that had larger embodied water. Therefore many case studies that had the greatest percentage increase in costs did not have the highest actual increase in costs. The individual elements, and thus materials, used were shown to have a significant impact on the effect of increased water prices on construction. The same factors and relationship that affected the degree of percentage increase and actual increase of total building costs also affect the individual elements and materials.

The price of water used directly for construction increased significantly, however the low prices charged for water to construction sites and the relatively low amounts used compared to the total embodied water kept the effect of large percentage increases to a minimum actual increase in costs, even at the highest rate of taxation. Although this seems to be a positive result for economic activity within the construction industry, builders will only rein in their inefficient building practices to the extent that it is beneficial for them to do so. Therefore it is likely that little change will occur to onsite building practices as a result increased water prices at any level.

Elements such as fixtures and fitments and many finishes are replaced over the life cycle of buildings. The materials that make up these elements such as carpet, MDF, plasterboard, vinyl and paint will need to be replaced numerous times depending on the their churn rate and life span of the building (Treloar et al., 1999). Therefore water embodied in these elements includes initial embodied water and recurrent embodied water. Consequently the additional costs as a result of increased water prices on these elements, will need to be considered not only initially but again many times over, making it important to use the lowest possible embodied water materials in them. The price increase in these particular materials and others that are replaced will have a significant impact on prices and therefore change consumer behaviour towards materials with low embodied water to reduce costs for consumable elements.
6. CONCLUSION

With increased water prices, the impact on the economy will vary. Industries, companies and projects with water intensive practices and materials will incur the greatest burden. As a result there has been a lack of industry support for such policy, stemming from ill informed concerns about harm to economic growth and industry competitiveness. The aim of this research was to investigate the effect an increase in water prices would have on construction. To do this a streamlined version of life cycle assessment was used, namely an embodied water analysis. The embodied water analysis used an input-output based hybrid approach to calculate the significance of water embodied in eight case studies. Three taxation scenarios were developed and applied to the embodied water of each case study. The initial business as usual costs of each case study were determined and used as a baseline to measure the significance of the effect on construction from each scenario.

It was found that although there is a considerable amount of water embodied in construction, the actual effect of increased water prices would be minimal unless implemented at a high rate. The already high cost of construction ensures that a rise in material and product prices as a result of increased water prices would have a marginal impact comparatively on the water intensive industry. The significance of water embodied in individual elements and materials confirms that their selection would dictate the effect of increased water prices more so than the onsite activities. The price of water used onsite for construction activity would increase significantly compared to the pre rise price, however the low price charged for water to construction sites and the low amounts used in the context of total embodied water would keep the effect of a large percentage increase to a small actual increase compared to the total costs of construction.

Although the minimal impact of the increased water prices would appear to be a positive result for economic activity within the construction industry, its environmental effectiveness is questionable without price signals to encourage a consumer shift. Even if large increases in the price of water were introduced creating in many instances substantial indicators, unless practical and visible lower embodied water alternatives are available, developers would suffer no competitive losses. Therefore it is likely that increases in costs would be passed onto the consumer. If this occurs, the push for change would come from consumers with little assistance from developers making higher profits from increased building costs.

It is widely recognized that the price of water is undervalued and will in the future rise. This may not be the result of a water tax but rather a general increase or the implementation of other economic instruments. This research has explored the uncertain effects of such policy on the construction industry by depicting the consequences of possible scenarios. Australia’s infrastructure and built environment is continually growing, therefore the water embodied in construction and its effects will continue to be an important issue.

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REFERENCES


