# WATER AND COAL – TRANSFORMING AND REDEFINING 'NATURAL' RESOURCES IN AUSTRALIA'S LATROBE REGION

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**ABSTRACT** Victoria's Latrobe Region is typically defined by its brown coal used for electricity production, but this focus obscures the complex histories and ecologies that underpin it. In this paper, assemblage theory is used to analyse the region's transformations and the core role played by not just coal but water and climate in shaping the region. A century of state sponsored coal development has resulted in the region's current economic reliance on fossil resources, but the recent closure of Hazelwood Power Station signals mounting pressures for decarbonising. In a climate of increasing constraints on coal use and uncertainties about water abundance, regional identities and resources are being redefined, highlighting the social co-construction of resources and regions. Analysis of the co-evolution and transformations of the region's carbon, water and society assemblages supports the idea of new assemblages emerging with altered carbon-water dynamics.

**Keywords:** regional transformations; water-coal relationships; Latrobe Valley; assemblage theory.

## 1. INTRODUCTION

This paper explores the intimate and evolving relationships between water and carbon in Victoria's Latrobe Region.

Water and coal were critical to the first industrial revolution and will be to the next, but for fundamentally different reasons (Bryan *et al*., 2013). Water and coal have a long, intimate history. The exhaustion of shallow coal pits and the flooding of deeper pits in eighteenth century England drove invention of better pumps. The need to dewater coalmines is credited with inspiring the internal combustion engine (Hobhouse, 2003; Grayling, 2016). James Watt's engineering company, Boulton and Watt designed and built the coal-fired steam engines that became the power plants of industrial mass production (MAAS, 2017; BBC, 2017). So

significant were the changes that followed this technological innovation that some, such as Paul Crutzen, consider that it defines the beginning of the Anthropocene epoch in which human influences are fundamentally transforming the Earth (Steffen *et al*., 2007).

With increasing acceptance that we are entering the Anthropocene, it is useful to critically reflect on the implications of changing conceptualisations of human relationships with water and carbon (Schmidt, 2017). In an era being defined by ideas about carbon and resource constraints, limits to growth and planetary boundaries, there is increasing recognition that water and carbon link local and global processes in manifold ways, playing vital roles in ecosystems, human cultures and planetary life support systems (Steffen *et al*., 2007; Rockström *et al*., 2009).

Concerns about climate and water security are increasingly entering into the social and political life in the Anthropocene, finding expression in a proliferation of national and multilateral policy agreements (see for example Schmidt, 2017; Alexandra, 2017). Managing carbon (in fuels, forests, soils, materials and the atmosphere) and water in its various forms (surface and ground water, in agriculture, cities and ecosystems) are some of the 21st Century's defining challenges (Steffen *et al*., 2007; Rockström *et al*., 2009; Molle, 2009; Alexandra, 2012).

In the Latrobe region of Victoria, Australia, these global concerns underlie growing pressure to decarbonize the economy and adaptively govern the economic and social impacts (Weller, 2012). The Latrobe Valley has been defined as a 'coal region' since early in 20th century, when its vast deposits of lignite were identified as a potential resource for the electrification of Victoria (Gibson, 2001). But less recognised in the construction of this region is the crucial role of water. In the Latrobe Valley, water has been essential to the region's development and identity, including but not limited to its role in enabling the lignite to be transformed into a useful resource. By focusing on water and coal, this paper investigates the ways in which regions and resources are co-defined and redefined. Section two examines the way the co-presence of water and coal helped to shape the Latrobe Region.

The theoretical starting point for this paper is that regions are created by the co-evolutionary dynamics of people and places (Allen, 2011). Regions evolve as assemblages, or complex systems of cultural, political and economic relationships with territorial resources like land, lakes, forests and minerals (Dittmer, 2013). Assemblage theory provides a framework for linking cultural and material elements across micro and

macro scales, spanning the personal and political, emphasising subjectivity, multiplicity and relationality (DeLanda, 2006; Duff, 2010; Fox and Alldred, 2014). Assemblage research emphasises the way relationships, networks, material and cultural elements combine and recombine to form socio-ecological systems (Dittmer 2013; Allen 2011; Fox and Alldred 2014). Supporting analysis of the combinations of the material, cultural, spatial and structural elements is useful for conceptualising nation states (Dittmer, 2013), regions (Allen, 2011) and cities (Fuller, 2013). Allen (2011) invites us to conceptualise regions as powerful networks of cultural, institutional and material relationships with histories and evolving futures, reordering and readjusting to multiple drivers of change. Assemblage methods provide a suite of accepted social research methodologies suited to investigating a diverse array of complex socio-ecological issues, processes and systems (Fox and Alldred, 2014; Duff, 2010; Dittmer, 2013; Fuller, 2013; DeLanda, 2006).

Like regions, resources are also socially defined. Cultural relationships to specific resources evolve due to changing knowledge, values, technological innovations, and policy imperatives – for example, slaves, canned black swans and koala skins were all once openly traded resources. Knowledge of how resources are culturally framed and values determined assists in tracking how societies' material-cultural relationships evolve with changing conditions, utilisation patterns and socialised dispositions. This propensity for resource characteristics to evolve as circumstances change is clearly apparent in divestment debates focused on whether fossil fuel reserves are a bankable investment asset or a pending carbon liability (Bullard, 2014; Ayling and Gunningham, 2017).

Throughout the 20$^{th}$ century, water has been framed as a resource for national development with state priorities for agricultural and industrial intensification aligning with increasing prowess in hydraulic engineering and private sector interests (Linton, 2010a; 2010b; Linton and Budds, 2014; Schmidt, 2017). Today, re-defining water's economic, cultural and environmental relations in ways which challenge instrumentalist resource framings are recognised as essential to sustainability transitions (Molle 2009; Marshall and Alexandra 2016; Schmidt 2017).

The continual adjusting and remaking of water resources, both physically and conceptually, has been defined as the hydro-social cycle (Linton and Budds, 2014). Like society's changing relationships to water, similar environmental-cultural relationships apply to other resources, including land, forests and fossil energy sources. In section three of this

paper, the hydro-social cycle - a relational-dialectical approach to the political ecology of water (Linton and Budds, 2014) - is expanded to characterize the major historical transformations of the Latrobe region. These water-carbon-society assemblages are examined synoptically to identify major changes that can be defined as re-forming and redefining the region and its trajectory (Allen, 2011).

By taking into account the scope and magnitude of historic transformations, the era of major expansions in coal-fired electricity generation in the Latrobe Valley can be seen as one of several assemblages that established a specific regional trajectory. The closure of Hazelwood Power Station in 2017 may mark the cusp of a major regional transformation when seen in relation to prior regional transformations. An assemblage lens also helps to illustrate the potential for emerging factors to drive new transformations. For the Latrobe these factors are many but may include opportunities arising from its industrial history, its changing but temperate climate, emerging bio-production technologies and newly defined landscape resources like bio-sequestration (Alexandra, 2012; Keith *et al*., 2009). Section four outlines how in combination these factors may frame opportunities for the Latrobe Region in a more water and carbon constrained future.

## 2. WATER WITH COAL - DEFINING THE LATROBE REGION

The Latrobe region is usually defined as by its coal and electricity production, but like all regional branding this is a simplification of complex socio-environmental relationships with their detailed stories, layered histories and rich ecologies.

The 'Latrobe Valley' typically refers to the valley's industrialised core with coalmines, power stations and the major towns of Moe, Morwell and Traralgon. These towns largely arose out of active State interventions to secure Victoria's industrial development through coal fired electricity generation (Gibson, 2001; Tomaney and Somerville, 2010; Eklund, 2017).

One set of these interventions was engineering the Latrobe River system to provide the reliable water resource needed for urban and industrial uses, including coal mining and electricity generation. In this sense the Latrobe River system can be seen to meander through all aspects of Victoria's coal fired industrialisation, provisioning energy, material and social production, its waters integral to the region's industries, landscapes and communities. The ancient coal beds are

steeped in water, steamed in the furnaces it links a century of coal-fired electricity generation with climates past and future.

The Latrobe River drains a basin of approximately 4 900 km$^2$ between the coastal Strzelecki Ranges and the southern fall of the Great Dividing Range. From its headwaters near the Baw Baw Plateau, the Latrobe River flows eastward to Lake Wellington in the Ramsar listed Gippsland Lakes (EPA, 2002; Southern Rural Water, 2014). Tributaries include the Thompson, Moe, Macalister, Tyers, Tanjil and Morwell Rivers (see Figure 1 and figure 4).

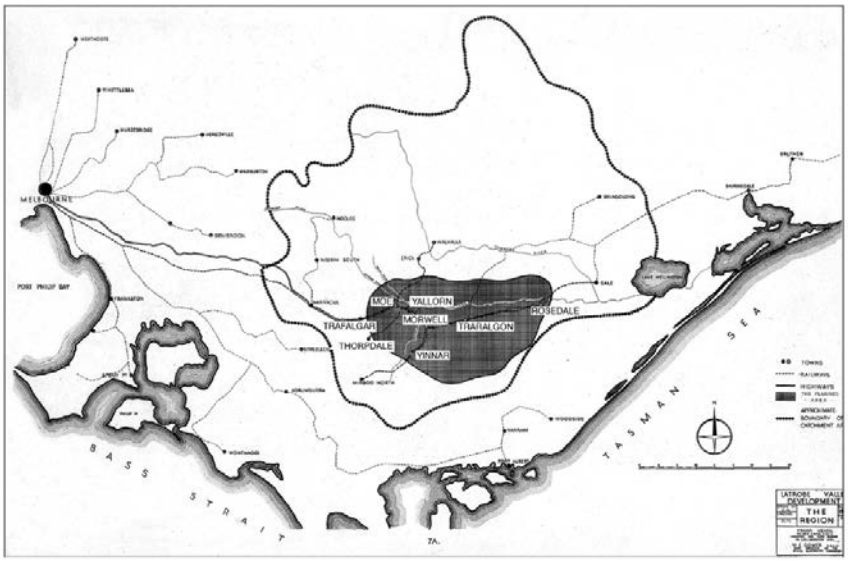


**Figure 1.** Map of the Latrobe Valley development region with major coal deposits and outline of the Latrobe River catchment as complied by Heath and Gower in 1947. Source: Gibson (2001).

Lying close to the Southern Ocean in the track of the global winds known as the 'Roaring Forties' the Latrobe Valley is frequently wet and windy. However, on still days, billowing clouds rise from the huge chimneys signalling the material transformations occurring within the coal fired electricity generators. These clouds are reminders that the power stations pump "out a steady light grey cloud of water vapour, fine ash and carbon dioxide" (Michin, 2005). Along with $CO^2$, water vapour is a major by-product of the thermal generators, making them appear as factories birthing clouds (see figure 2). Once acclaimed as impressive

symbols of the modern state these massive industrial installations have been redefined in the 21st century as icons of the imperative for reducing $CO_2$ emissions (Eklund, 2017; Environment Victoria, 2017). Despite $CO_2$ being invisible, the gaseous exhausts emanating from these structures are often used as visual symbols of the carbon pollution fundamentally altering the composition of the global atmosphere where it is 'breaching' what Rockström *et al*. (2009) define as a critical planetary boundary

**Figure 2.** Hazelwood Power Station. Source: ABC http://www.abc.net.au/news/2016-07-12/hazelwood-power-station-in-the-la-trobe-valley/7622086.

Water and carbon link small-scale biological processes with broader regional and global processes. These ubiquitous materials connect life at all scales, from the intercellular to the intercontinental, circulating through all life forms, including us. Carbon surrounds, in soils, the atmosphere, plants and animals and in gigantic fossil deposits, like those underlying Victoria's Latrobe Valley (Allardice, 1991). Fossilised remains of Eocene and Miocene forests lie up to 165 metres deep, formed by Gondwanna forests of species including Antarctic Beech (*Nothofagus*) and Kauri (*Agathis*) (Holdgate *et al*., 2009) whose modern relatives grow in the moist forests of New Zealand, Chile and Australia (Mao *et al*., 2012). In the youngest coals, the Yallourn measures, the drying climate

of the Middle Miocene optimum is indicated by increased charcoal from forest fires and fossils of sclerophyll vegetation (Holdgate *et al*., 2007).

Burning the vestiges of these ancient forests for electricity generation has sustained Victoria's demand for electricity for almost a century (Tomaney and Somerville, 2010). While often "celebrated as a cheap source of power, helping build a manufacturing industry in Victoria worth $23 billion a year" reliance on this electricity makes Victorians the world's heaviest per capita emitters of $CO_2$ (Michin, 2005). Consequently, the electricity generation industry is under increasing pressure to decarbonize with flow on social and economic impacts (Weller, 2012).

Development of the coal for electrification required substantial, multi-faceted state interventions and centralised planning (Gibson, 2001; Eklund, 2017) including ensuring the provision of adequate water for power station cooling, steam production to drive turbines and for towns and industry.

The *co-presence* of water and coal in the Latrobe Valley helped to catalyse the construction of power stations close to the lignite deposits. The water content of the brown coal has long been deemed a problem because at between 50 per cent and 70 per cent water by weight (Allardice, 1991) the brown coals are too wet, heavy and low grade to be exportable, having heating value about a quarter of many black coals (Geoscience Australia, 2017). Large-scale utilisation of the high moisture coal has been limited to locations proximate to mines, requiring nearby dams to supply the reliable water needed for electricity generation. Therefore the character and spatiality of the lignite and water resources were catalysts for the infrastructural and sociocultural dimensions of the region's industrialization. In this sense, the region can be usefully defined as an evolving carbon-water-society assemblage due to the complex material-cultural relationships that shaped it.

## 3. REGIONAL TRANSFORMATIONS PAST AND PRESENT

In his introduction to Duggan's (1987) history of Gippsland - '*The Ash Range*' - Don Watson articulates the idea that to see the extraordinary nature of our era requires informing our perspectives through the lenses of history. This section sketches out several historical transformations that emphasise the changing assemblages of water, carbon and society in the region.

In the few generations since the violent dispossession of the Kurnai-Gurnai people, Gippsland has gone through major transformations, including the eras of squatters, gold rushes and small farm settlements (Duggan, 1987; Watson, 2011) followed by the State constructing power stations and new towns (Gibson, 2001; Tomaney and Somerville, 2010; Eklund, 2017). Using assemblage research methodologies based on Fox and Alldred (2014) each phase can be defined as regional assemblage due to the way fundamental material and cultural relationships have been re-assembled into new patterns or complex systems of relatedness (DeLanda, 2006; Dittmer, 2013; Allen, 2011). Each phase helped shape the contemporary assemblage in the region. Each transformation is also a hydro-social transition due to the way the political ecology of water evolved (Linton and Budds, 2014).

In the late 1830's Scottish highlanders - dispossessed from their own territory due to the highland clearances - colonised Gippsland, leading livestock south from the Monaro districts (Watson, 2011). Angus McMillian working for Lachlan MacAlister travelled overland almost certainly using indigenous road networks through the mountains (Watson, 2011; Blay, 2016). On the plains, McMillian rode through extensive grasslands swarming with emu and kangaroo - the managed landscapes of the Kurnai/Gurnai (Gammage, 2011). Reminding McMillian of Scotland, he named the country "*Caledonia Australia. Here was a country lying dormant capable of supporting all my starving countrymen*" (Duggan, 1987, p. 47). McMillian was witnessing a co-evolved landscape resulting from a fairly stable carbon-water-society assemblage with its managed grasslands, rain fed waterways and established society-ecology interrelationships (Griffith, 2002; Gammage, 2011; Blay, 2016).

The arrival of squatters caused massive disruptions to these long stable socio-ecological assemblages (Griffith, 2002), before they established their own ordered and genteel Victorian era society based on systemic dispossession (Watson, 2011; Duggan, 1987). Watson (2011) also points out that the names 'Gippsland' and 'Latrobe' that now designate the region are tributes to minor colonial officials, but that by renaming a place a territorial claim is made that redefines its identity and rewrites its history. Of course, there are other names. In the Tatungalung and Braiakaulung languages of the indigenous KurnaiGurnai people the Latrobe River was known as Durt'yowan (meaning 'Finger') or Tanjil (meaning snow or frost) (Government of Victoria 2017a; 2017b; 2017c). These names remind us of cultural understandings and bio-regional

governance systems that were abruptly disturbed, fundamentally altering social and environmental relations in the area, now known as Gippsland (Duggan, 1987). Acknowledging the existence and legitimacy of other, less dominant ways of naming and knowing places can reveal the ways in which regional identities are profoundly socially constructed, while also illuminating human connections that span millennium (Gammage, 2011; Blay, 2016).

The loss of traditional hunting grounds and grassland resources so attractive to the squatters led to organised armed resistance (Kerkhove, 2014) and retributions, some claim was genocidal violence (Duggan, 1987; Watson, 2011) but in contrast, the next post colonial resource rush was for a material the Indigenous nations had neither used nor valued – gold. An influx of gold miners spreading out through Gippsland using overland tracks and coastal shipping drove the next transformation. The coastal waters, rivers and lakes were the main transportation system until the railway linking Bairnsdale to Melbourne was completed in 1879 (Synan, 1989). In this phase an assemblage of factors, like the thousands of 'diggers' and speculative capital attracted to the Victorian Gold Rushes combined with advances in mining and transport technology, contributed to the region's transformation (Duggan, 1987).

The third transformation occurred during the settlement land boom that followed Victoria's gold rushes. Selectors developed the small farms typical of Gippsland, fundamentally reshaping the region, building settlements, villages and towns, sawmills and networks of railways (Watson, 2014). Closer agricultural settlement required clearing the dense forests, their size indicated by a simple steel monument in the Strzelecki Ranges close to the Latrobe Valley. This marks the site of the world's tallest flowering tree that stood 115 metres tall before it was felled to measure it in the 1880's (Alexandra, 2015) (Figure 3.).

To promote further agricultural development the Victorian Government built irrigation systems on the Macalister River and drained the Moe swamps. During the first half of the 20th Century, the State Government resumed many failed farms in the 'heartbreak hills' of the Strzelecki Ranges, reafforesting them with pine and mountain ash, plantations that became a significant source of timber and wood fibre for industries in the Latrobe Valley (Noble, 1986). These stages of deforestation and reafforestation represent an evolving carbon-water-society assemblage with key relationships between the land and forests, rain-fed agriculture and settler society (Griffith 2002).


**Figure 3.** The World's Tallest Tree Monument in the Latrobe Valley. Source: Photo Jason Alexandra.

The Government's active development of coal industrialisation was the fourth major transformation with the State Electricity Commission (SECV) formed in 1921 to develop coalmines and power stations (Gibson, 2001; Eklund, 2017). It became the leading institutional driver "*of Victoria's distinctive state-led developmental agenda*" which the State Premier, Henry Bolte proudly proclaimed was "*the largest and most comprehensive use of State power outside Russia*" (Tomaney and Somerville, 2010). Speaking optimistically in 1956, Henry Bolte paid tribute to the great dividends of Victoria's electrification, describing the Latrobe Valley as the 'Ruhr of Australia' and comparing it to great industrial centres like Birmingham and Pittsburgh (The Argus, 1956).

It was not just coal that enabled this productivity. The rivers of the Latrobe system contributed to State and regional development with dams such as Blue Rock Reservoir constructed to provide the reliable water needed (Boon *et al*., 2016). The Morwell and Latrobe Rivers illustrate the scale of hydraulic engineering undertaken. The Latrobe River was comprehensively desnagged – removing the fallen trees or 'snags' (Erskine and Webb, 2003) - channelized and straightened reducing its length by 25 per cent (Reinfelds *et al*., 1995). Similarly, the Morwell

River has been comprehensively re-engineered, re-routed six times to provide access to mine coal, and after the mine wall collapsed in 2007 it was used to dispose of the polluted water that had flooded the mine (Anton, 2017).

Numerous large dams have been constructed in the Latrobe Basin for agricultural, urban and industrial purposes, altering the flow regimes of the rivers (Gippel and Stewardson, 1995). However, with changing social values in the 1980s and 1990s environmental water needs have been more formally recognised (Boon *et al*., 2016; Marshall and Alexandra, 2016). For the Ramsar listed Gippsland Lakes, environmental flows were formalised after water flowed to Melbourne from the Thompson Dam (Gippel and Stewardson, 1995). The decision to build the 1 123 gigalitres of storage high in the Baw Baw Ranges was triggered by severe water restrictions in Melbourne during the 1967 drought (see figure 4).

For decades the rivers functioned as open drains for polluted wastes from power stations, coalmines, factories, dairies and towns resulting in the Latrobe River being Victoria's most polluted stream (Victorian Parliament, 1957). Eventually industrial and urban wastewater was piped east severely polluting Lake Coleman. In the late 1980's, the Gippsland Water's Coalition – a regional alliance of environment, industry and social justice groups – successfully campaigned to stop the pollution flowing into the Gippsland Lakes. The waste from the Gippsland Outfall Sewer was redirected to Bass Straight and Lake Coleman gradually restored after pollution ceased (Samson and Howard, 1991). The construction of large-scale dams, wastewater systems and coal-fired power stations demonstrate the increased interventions of the state in shaping the carbon-water-society assemblages in the region throughout the 20$^{th}$ century.

The fifth major transformation occurred in the early 1990's with privatisation of the electricity industry (Gibson, 2001). Ownership was transferred to large corporations in a policy shift that aligned with dominant pro-market political philosophies (Pusey 1991; 2003). The loss of more than 8 000 jobs profoundly altered the region creating the "most disadvantaged location in regional Victoria" (Tomaney and Somerville, 2010). This disruption motivated the search for new economic directions with research on how the region could "enact a politics of becoming … within alternative visions of Economy and Region" (Gibson, 2001). It also demonstrates that as assemblages, regional economies are always in the process of continuously becoming, sometimes gradually and sometimes more suddenly.

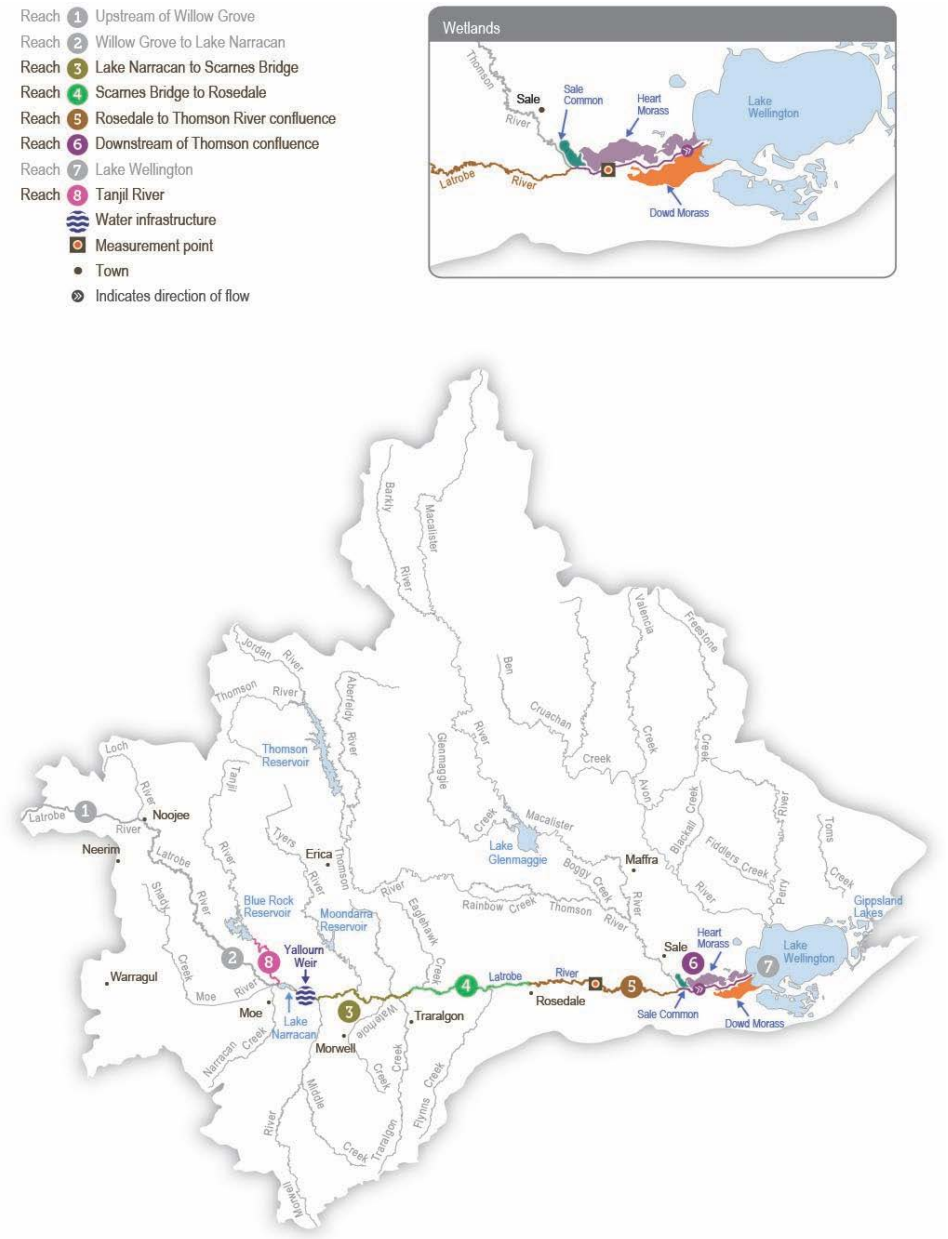


**Figure 4.** Latrobe Basin with Major Tributaries and Environmental Watering Sites. Source: Victorian Environmental Water Holder (2017).

## 4. REGIONAL TRANSFORMATIONS – PRESENT AND FUTURE

With the closure of the Hazelwood Power Station a possible catalyst for the next transformation in the regional assemblages, exploring alternative visions and the politics of becoming continues to be central to the future of the Latrobe Valley. The closure marks a significant turning point in the trajectory started a century ago that cannot be divorced from deepening concerns about climate change and the need to decarbonise the economy (Weller, 2012). While Hazelwood's closure occurred after many years of campaigning by environment groups and The Greens Party (see figure 5), many factors contributed to the final decision taken by the French multi-national, Engie, to close the power station, including reputational risks in the context of the Paris Climate Agreement and the politics of carbon, alternative technological investment options and the inefficiencies of the aging power station (Environment Victoria, 2017; Eklund, 2017).

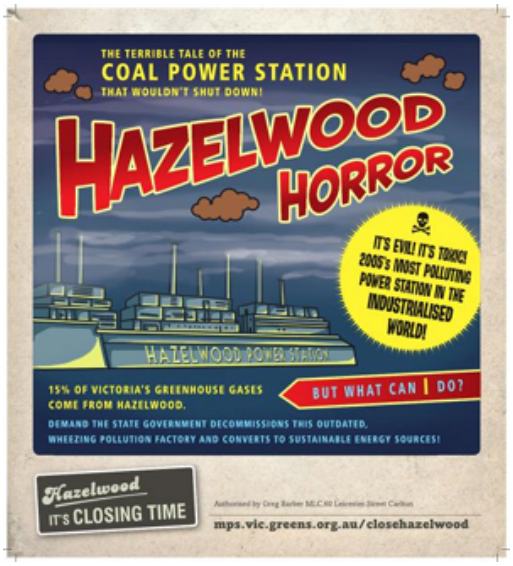


**Figure 5.** Greens Party Advertisement Calling for the Closure of Hazelwood. Source: https://www.sourcewatch.org/index.php/Hazelwood_Power_Station.

With the closure of the Hazelwood Power Station, the co-presence of water and coal can be seen to have shaped the Latrobe Region in several overlapping ways, reflecting longer-term feedbacks and couplings in the water - carbon - society assemblages. Firstly, the region's wet brown

coals have high intensity $CO_2$ emissions per unit of electricity produced. Secondly, this pollution intensity marks the region's generators as a high priority for climate change responses making the region vulnerable to decisions that trigger significant social and economic impacts (Weller this issue). Thirdly, the coalmine fire of 2014 caused significant reputational damage to Engie resulting in penetrating scrutiny, including two Royal Commissions (Victoria Parliament, 2016). Problems were exacerbated by inadequate water for fire suppression and the toxicity of the available water causing illnesses amongst fire fighters (Doig, 2015). Fourthly, the Royal Commission recommended that Hazelwood's corporate owners rehabilitate the mine, with the favoured option a pit lake (Victoria Parliament, 2016). Finally the region faces many uncertainties, including the prospect of reduced quantity and reliability of rainfall due to a predicted drying trend (CSIRO, 2010; 2102). Reductions in rainfall, runoff and stream flow would affect rivers, lakes and climate dependent industries including agriculture and forestry reducing their viability and generating additional impacts.

An uncertain future climate has profound implications with impacts cascading through ecosystems, altering carbon and water relationships at landscape scales (Alexandra, 2012). For example, an increasing frequency and severity of wild fires would result in regime shifts in the mountain and alpine ash forests (Lindenmayer *et al*., 2011). Climate shifts and forest fires cause succession in vegetation communities that can reduce catchment scale water yields and flows to streams and rivers (Donohue *et al*., 2011) particularly from the ash forests in the ranges that form the headwaters of the Latrobe river systems (Langford, 1976; Vertessy *et al*., 2001).

Competition and contestation over water resources is predicted to feature in a resource-constrained future (Schmidt, 2017; Alexandra, 2017). After Hazelwood the preferred mine rehabilitation option of a pit lake has many unresolved water quantity, quality and groundwater issues (Hussey *et al*., 2008; Victoria Parliament, 2016). The Hazelwood Mine Inquiry called for Government agencies to plan water allocations for the lake of 740 gigalitres – or about 1.5 times the volume of Sydney Harbour - that may take decades to fill (Victoria Parliament, 2016) and may compound existing pressure on the Gippsland Lakes (Boon *et al*., 2016; Environment Victoria, 2017). Southern Rural Water (2014) states that the "Latrobe River Basin is fully allocated, so no new licences can be issued" so presumably water required would need to be transferred from existing licence holders including environmental allocations.

If it goes ahead, the lake may become a striking monument to the end of the era of state development based on coal-fired electrification and symbolize the emergence of a new assemblage driven by new imperatives and opportunities.

Many are explicitly questioning whether the region can be further unharnessed from its coal orientated past (Environment Victoria, 2017). Negotiating the opportunities of a carbon and water constrained global future could aid in driving the next regional transformation. In landscapes, like those of Gippsland, the living carbon sinks - the lakes, farms and forests - are being redefined as valuable for their carbon sequestration capabilities (Keith *et al*., 2009). The next generation of plantations may also represent an emerging asset class based on combining industrial uses and ecosystems services including carbon sequestration (Alexandra, 2012; 2015).

Similarly, relatively abundant water, a mild climate and cultural and industrial infrastructure may provide strategic advantages for the Latrobe region if these capacities enable diversification of the economy (West, 2009; 2013; EU, 2017). These attributes may attract investments in new bio-industries based on a new generation of plantations, crops and subsequent downstream processing. Europe is accelerating the development of bio-based industries as central to the EU's bio-economy strategies because of their capacity to produce renewal bio-materials in a carbon-constrained world (Hagemann *et al*., 2016; McCormick and Kautto, 2013; Scarlat *et al*., 2015). It is conceivable that emerging material technologies in Europe could also engender new assemblages of bio-industrial ecologies in the Latrobe region, assisting in revitalising its economy and industrial culture.

Country to country transfer of technical and other support has been significant in the global spread of technological and regional development models (Schmidt, 2017). Half a century after Sir Henry Bolte's drew inspiration from the Ruhr Valley it may again be useful to look to the Ruhr for regional development analogues that could assist in redefining the development trajectory of the Latrobe Valley. Specifically, it may be instructive to look to Essen, the former coal and steel city in the Ruhr Valley that adopted a comprehensive reform program. It focused on mobilising citizens and businesses in transformational change that comprehensively altered the social, economic and urban metabolism of the region, resulting in the award of the EU Sustainable Cities Award of 2017 (EU, 2017).

## 5. CONCLUSION

Brown coal used for electricity generation has been a defining feature of the Latrobe Region, intrinsically linked to its social and economic fabric for a century (Weller, 2012). While coal has been defined as a natural resource its utilisation patterns have been both deeply political and cultural (Eklund, 2017). Water also flows deeply through the regions history and landscapes, co-constituting the formation of its identity and enabling the coal to be used for state development.

The use of an assemblage theory informed analysis of the Latrobe regions allows us to see that like water-society relationships existing in the hydro-social cycle (Linton and Budds, 2014) other socio-material relationships are also dynamic. It is possible to see that carbon exists within a carbon-social cycle with complex feedbacks and couplings that span from local to global, including through the influence of globally agreed $CO_2$ emission targets.

The era of brown coal industrialisation in the Latrobe region can be seen as one of several transformations by examining the evolution of the water-carbon-society assemblage that reveals several prior disruptive socio-environmental transformations. These also reveal that the way we understand and manage water and carbon is changing contributing to the redefinition of resources. For example, the carbon sequestration capacity of landscapes is becoming recognised as a resource (Alexandra, 2012; 2015) while high $CO_2$ content coals are being actively redefined by the divestment movement with its calls for more strenuous efforts to weigh up the financial and political risks involved in releasing the fossil carbon stored in fossil fuels (Bullard, 2014; Ayling and Gunningham, 2017). These examples demonstrate that resources are dynamically and culturally defined within material-cultural assemblages, that are contingent and context specific, their socialised valuations and definitions determined within evolving networks of relationships.

By helping to reveal the myriad relational processes continuously adjusting and reshaping regions, assemblage theory supports inquiry into the evolution of regions as complex and dynamic systems that are continuously becoming, incorporating both their histories and their future trajectories (Allen, 2011; Dittmer, 2013). Institutional path dependence occurs when contemporary cultural and institutional dynamics and historical contingencies and circumstances align to constrain future trajectories; however, regional futures are not entirely locked in by their past (Gibson, 2001; Marshall and Alexandra, 2016). They have a range of

possible trajectories or 'flight paths' so that radically different future trajectories are both conceivable and possible as regions incorporate and adjust to new imperatives and drivers of change (Allen, 2011; Dittmer, 2013).

The application of assemblage concepts supports the conclusion that regional identities and definitions of resources are culturally determined and will therefor continue to evolve as multiple processes. In addition, relationships in business, communities and civil society influence the way these are shaped and reshaped. These include dominant values, beliefs and ideals, policies and practices, and science and technologies. Together these are altering the way specific resources like water and carbon are defined and redefined within assemblages of cultural-material relationships that will continue to unfold and evolve. The way we conceive of and define resources and regions frames and constrains future possibilities, literally shaping the future flight paths of the regions we inhabit.

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