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Research

Transformation from "Carbon Valley" to a "Post-Carbon Society" in a Climate Change Hot Spot: the Coalfields of the Hunter Valley, New South Wales, Australia

Geoffrey R. Evans [1]

ABSTRACT. This paper examines the possibilities for transformation of a climate-change hot spot—the coal-producing Hunter Region of New South Wales, Australia—using complex adaptive systems (CAS) theory. It uses CAS theory to understand the role of coal in the region's history and efforts to strengthen the ecological, economic, and social resilience of the region's coal industry in the face of demands for a shift from fossil fuel dependency to clean, renewable energy and genuine resilience and sustainability. It uses CAS theory to understand ways in which the resilience of two alternative futures, labeled "Carbon Valley" and "Post-Carbon Society" (Heinberg 2004), might evolve. The paper discusses ways in which changes implemented through the efforts of local communities at local, smaller scales of the nested systems seek to influence the evolution of adaptive cycles of the system at the local, national, and global scales. It identifies the influences of "attractors," defined as factors driving the evolution of the system, that are influential across the panarchy. These include climate change threats, markets, regulatory regimes, political alliances, and local concerns about the environmental and social impacts of the Hunter's coal dependency. These factors are weakening the apparent resilience of the coal industry, which is being propped up by the coal industry corporations, labor unions, and governments to maintain coal dependency in the Carbon Valley. Moreover, they are creating an alternative basin of attraction in which a Post-Carbon Society might emerge from the system's evolutionary processes.

Key Words: *climate change; coal; complex adaptive systems; Hunter Valley, Australia; panarchy; resilience; sustainability; transition*

INTRODUCTION

The Hunter Valley of New South Wales (NSW), Australia is located 150 km (93 miles) north of Sydney and extends 200 km (124 miles) inland from the coast (Fig. 1). The Hunter Valley (also known as the Hunter Region) occupies almost 30 000 km^2 (11 583 square miles) of the catchment of the Hunter River with rich alluvial soils, densely forested hills, wetlands, and coastal estuaries (Geary et al. 2000).

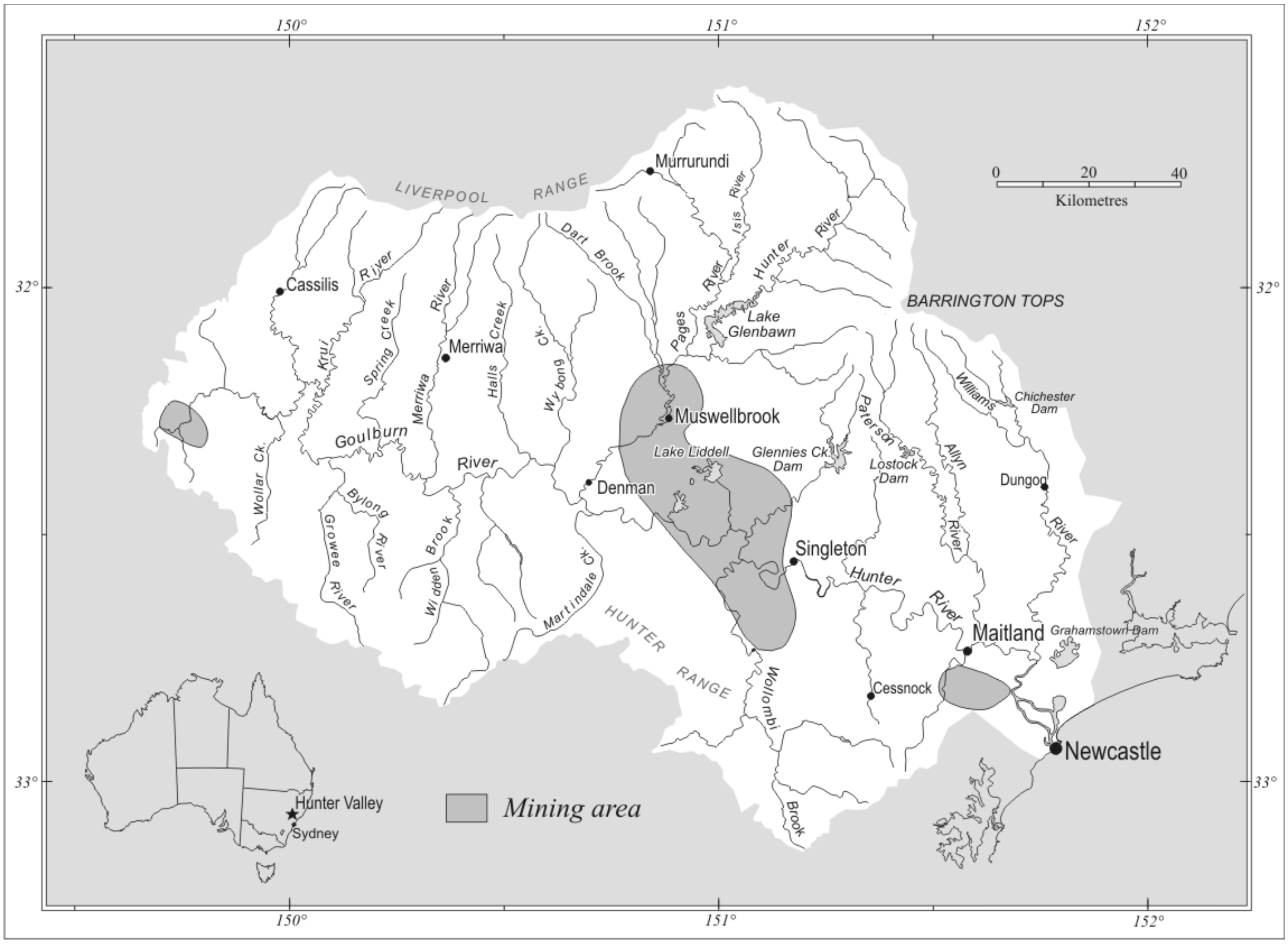
The Hunter Valley is also endowed with vast reserves of coal. Coal is Australia's largest export commodity, and the Hunter is the largest single source of thermal coal exported from Australia. Coal also fires 80% of Australia's domestic electricity supply, with 40% of this supply generated at five coal-fired power stations located in the Hunter. Cheap electricity has been a catalyst for the location of steel making, shipbuilding, aluminum smelting, and metal processing and manufacturing in the Hunter.

Hunter coal is Australia's largest single source of carbon dioxide (CO_2) emissions to the atmosphere: directly through the emissions from the coal-fired power stations in the region, and indirectly from combustion of the one hundred million tonnes of Hunter coal burnt annually in power stations in Japan, Taiwan, Korea, and other export markets.

The local ecological and social impacts of vast coal mines and power stations on landscapes, water, air, biodiversity, and human health, and the contribution of the region's economy to climate change are causing growing concern among local residents,

[1]University of Newcastle (Australia), Ecosystem Health Research Group

Fig. 1. The Hunter River catchment with the major current coal mining area concentrated around the towns of Singleton and Muswellbrook (Map courtesy of O. Rey-Lescure, Ecosystem Health Research Group, University of Newcastle).



with many now believing that the costs of coal dependency outweigh the benefits (Hunter Valley Research Foundation (HVRF) 2007b).

This paper examines the Hunter Valley as a case study of a complex adaptive system (CAS) integrally linked to the processes of global warming and climate change at local and global scales. The paper considers a potential process of transformation from the Hunter Valley's current status as "Carbon Valley," as it has been referred to in the local media (Ray 2005a) to an alternative more ecologically and socially sustainable system, a "Post-Carbon Society" (Heinberg 2004).

The Hunter Valley's CAS is an example of a social–ecological system that has been relatively stable for many decades, and appears to be quite resilient—having capacity to withstand pressures for change and to recover from shocks (Resilience Alliance 2005)—but is under pressure from coal mining, climate change, and the links between them.

The paper uses the adaptive cycle metaphor and Gunderson and Holling's (2002) theory of resilience and adaptive cycles to explain how the Hunter Valley's current social–ecological system might evolve from its current Carbon Valley status to a Post-Carbon Society. The resilience of the Hunter

Valley's current social–ecological system is influenced by various ecological and social disturbances and factors. Influencing factors in the Hunter Valley include linked ecological and human health distress from coal mining at the local scale, local and global impacts of climate change, and social and political responses to coal mining and climate change at local and global scales.

Carbon Valley

The Hunter Valley's Carbon Valley title was attached by the region's major newspaper, the Newcastle Herald, which identified the region as "a greenhouse capital... in one of the world's biggest per-head producers of global warming gases" (Ray 2005a: page 1). The alternative scenario, a Post-Carbon Society, would have an economy based on renewable energy sources, reduced per capita resource usage in wealthy countries, a refocusing of economies from global back to more local markets, and dramatically improved environmental conditions and social equity (Heinberg 2004).

Some Hunter residents have used the term "Beyond Coal" to describe their aspiration for a Post-Carbon Society demonstrated in a human sign depicting these words on Newcastle's Nobbys Beach on International Climate Action Day, November 2006 (Fig. 2).

Ecological and social resilience and its opposite, vulnerability, are linked to adaptive capacity—the ability to shape change in response to disturbances (Berkes and Folke 1998, Folke et al. 2004, Resilience Alliance 2005, Gallopin 2006, Lebel et al. 2006, Olsson et al. 2006). Open dynamic systems, such as the Hunter Valley's social–ecological system, respond to disturbances in their internal and external environments.

Disturbances from climate change are challenging the sustainability of ecosystems and communities throughout the world. A shift to a low-carbon economy, a Post-Carbon Society, in response to climate change threats exposes potential vulnerability of coal-dependent economies. However, if communities, governments, and industries in regions like the Hunter Valley build their adaptive capacity, they can use climate change threats as an opportunity to reduce vulnerability as they restructure human–ecological and human–human relationships toward ecosystem health and a clean energy economy (Adger et al. 2005, Adger 2006).

Coal communities like the Hunter Valley are vulnerable on two counts; the mining process harms local ecosystem and social health and thereby weakens social and ecological capacities to respond to external threats, and a community whose economy depends on coal may be left marginalized and impoverished if global energy systems more to clean, renewable energy. The capacity of the Hunter Valley's social–ecological systems to achieve sustainability will be influenced by the capacity of ecosystems and human communities living in them to respond to disturbances, and if necessary, adopt the cultural values, take the political action and make the social and financial investments to create an alternative economy.

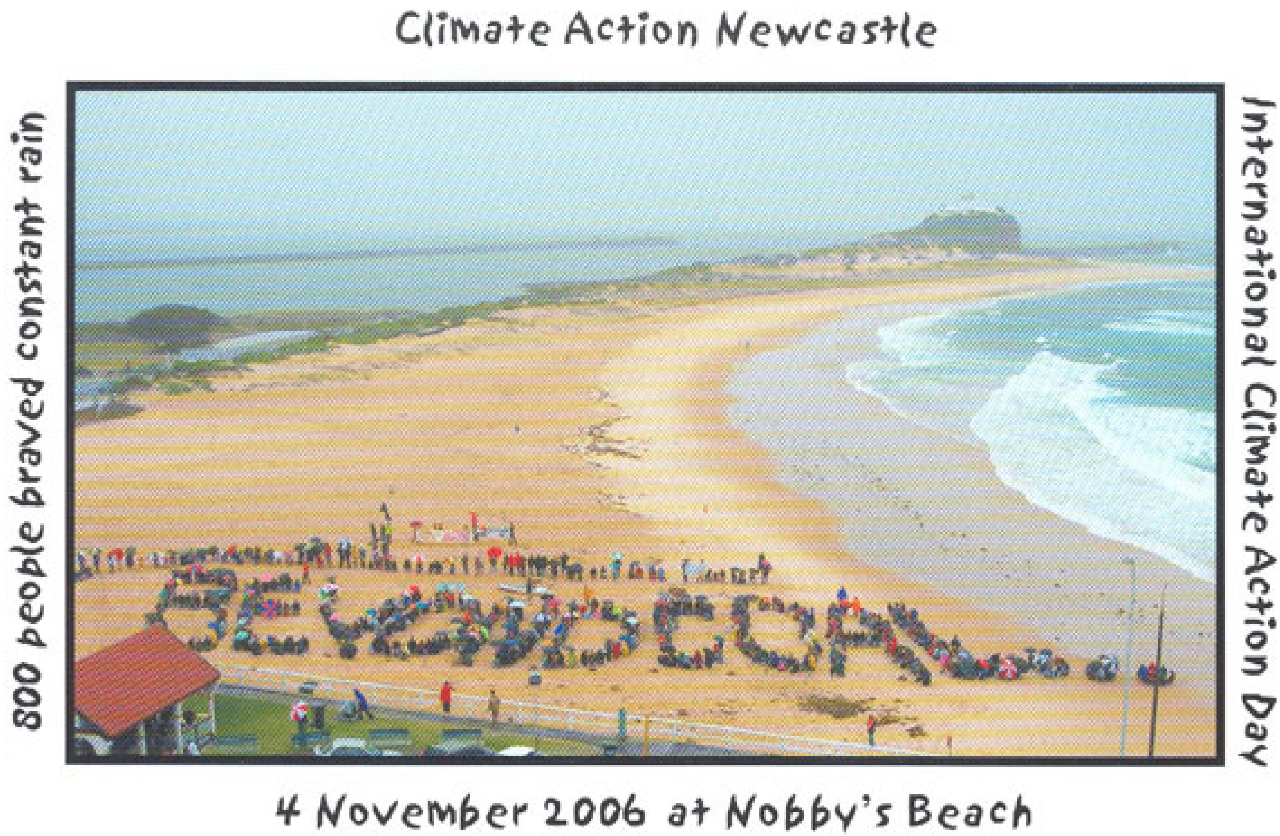
This paper outlines a narrative of the potential transformation of the Hunter Valley's current Carbon Valley CAS. It provides a brief overview of research that exposes loss of ecosystem and social health in the region, and therefore, resilience and sustainability, and uses panarchy theory to identify a potential pathway of planning a strongly grounded, more genuine resilience as the social–ecological system moves toward a Post-Carbon Society.

A Brief History of Coal in the Hunter Valley

Coal has been, and continues to be, a powerful influence on the drivers of the social–ecological evolution in the Hunter Valley. A brief history of these influences follows.

People have lived in the Hunter Valley for up to 60 000 years as part of the world's longest surviving human culture—indigenous Australians (Turner and Blyton 1985, Brayshaw 1986, Miller 1985, Albrecht 2000). The Awabakal, the indigenous people of the Newcastle district, called coal "nikkin" (Grothen 1988) and, according to Awabakal elder Ken McBride, they burnt coal found on the ground, beaches, and cliff faces for cooking and heating, and also used it as an insect repellant and for making tar to waterproof their canoes (McBride 2003). The Awabakal have a "dreaming" story that describes the creation of coal, in which it is a combination of both darkness and light in the world. Fearing its potential for harm, the story says,

Fig. 2. Postcard from Newcastle: a human sign depicting Hunter community aspirations for a regional economy “Beyond Coal” (reproduced here courtesy of Climate Action Newcastle).



the Awabakal believe their ancestors covered the extensive bands of coal found on the ground with rocks, sand, and plant material, burying it underground and pressing it under the earth as generations of families walked over the ground under which it lay (Williams 2006).

The British government established a convict settlement at what is modern-day Sydney in 1778, and the first British settlement in the Hunter Valley was a convict camp established to mine coal. Coal mined from the settlement, initially called Coal River, and later Newcastle, was the first profitable export from Britain’s Australian colony (Comerford 1997: page 251). The town of Newcastle emerged from a network of coal mining villages, many named after mining towns in England and Wales, such as Wallsend, Gateshead, Lambton, and Cardiff. Coal was also mined in Lake Macquarie, south of Newcastle, as early as 1842, when the Reverend Lancelot Threlkeld started the Ebenezer Coal Works at Skye Point, and after being refused convicts, used Aborigines for labor instead (Ross 1970).

The arrival of European settlers opened up a new phase in the evolution of the Hunter Valley social–ecological system. Within a few decades, the subsistence indigenous human–ecological relationship was overwhelmed by an agricultural and industrial mode of production. By the mid 1800s the indigenous people had been dispossessed of their land and lost their capacity to nurture it (Miller 1985, Turner and Blyton 1985, Brayshaw 1986, Blyton et al. 2004). Indigenous land management was replaced by a radically different regime in which the new settlers saw themselves as “the overpowering people who thus “Multiply, Replenish and Subdue the Earth”” (Threlkeld (ca. 1824) in Gunson 1974: page 6). They saw their mission as transforming the local environment through “subdue[ing] the growths of scrub, brush and forest covering the land” and “taming of the river and the sea” (Hunter Valley Cooperative Dairy 1953: page 4). Forests were cleared, rivers dammed, wetlands drained, and towns, ports, roads, mines, and heavy industry constructed (Armstrong 1983).

The Hunter Valley is one of the major coal export regions of the world. More black coal is exported through the Port of Newcastle than any other in the world (Newcastle Port Authority 2006). The price of coal has doubled over the 5 years from 2002–2007 to over A$100/tonne, sparking a coal rush in Australia’s major coal export regions.

By 2007, there were 33 coalmines in the Hunter Valley and Lake Macquarie. A further 27 new mines or mine expansions are underway or proposed, mostly in the Upper Hunter and the nearby Gunnedah Basin (New South Wales Department of Primary Industries (NSW DPI) 2006: pages 28–30). The scale of the new open-cut mines is vast, covering over 500 km^2—one sixth of the central Hunter Valley (Connor et al. 2004). Some mines, such as the Mt. Arthur mine cover 40 km^2 (15 square miles) (see Fig. 3).

The Hunter Valley coal chain is an extensive, multi-billion dollar network of public and privately funded infrastructure of mines, railways, port, coal loaders, and ships that link the region’s coal reserves to global markets. At the local level, the relatively cheap energy generated from the region’s coal-fired power stations has been a foundation of a heavy-industry economic base of steel making, metal processing, ship building, aluminum smelting, and metal engineering.

For 80 years, the Newcastle steelworks were the “material and symbolic identity” of the Hunter, with Newcastle known as Australia’s Steel City (Winchester et al. 2000). Coal mining and power generation industries are significant employers, especially in the Upper Hunter, but most of the region’s workforce is employed in education, health, hospitality, and business services. The region has well-developed manufacturing and agriculture sectors, including world-renowned wine growing and thoroughbred horse-breeding industries (HVRF 2007a; Fig. 4). The CSIRO, the Australian Government’s major research institution, established a major renewable energy (and “clean coal”) research center in Newcastle following the closure of the Newcastle steelworks in 1998. This renewable energy research capacity, along with the region’s other energy, mining, manufacturing, agriculture, and services infrastructure, provides adaptive capacity within the Hunter Valley’s complex adaptive systems.

ECOLOGICAL CHANGE AND COMMUNITY RESPONSES

Healthy ecosystems, “the state of a community of organisms (including humans as part of that community) that interact with their environment” (Rapport 2003: page 29), are the foundation for ecological and social sustainability. Ecological systems within the Hunter Valley have been radically transformed by human activity over the last 200 years. The combination of agriculture, mining, and urbanization has removed much of the biodiversity of the region and caused great ecological stress to the Hunter River catchment. Various studies have identified the dimensions of this ecological stress and loss of sustainability in the Hunter Valley (see Albrecht and Gutberlet 2000, Ray 2005a–h, Evans 2005a, b).

The NSW State Government’s own Healthy Rivers Commission, which investigated the health of all NSW rivers, described the Hunter River catchment as generally worse than that of other NSW coastal streams (Healthy Rivers Commission of NSW 2002: page 11). Vegetation studies have documented that 99% of the vegetation of the central and lower Hunter Valley floor has been cleared (Peake 2006). Studies of the cumulative impacts of mining have identified threats to the region’s remnant vegetation and aquifers (NSW Department of Urban Affairs and Planning (DUAP) 1997, NSW Department of Planning (DoP) 2005). Studies on dust, sulfur dioxide and nitrous oxide emissions in the upper Hunter Valley show levels of air pollutants significantly higher than the NSW average (Connor et al. 2004).

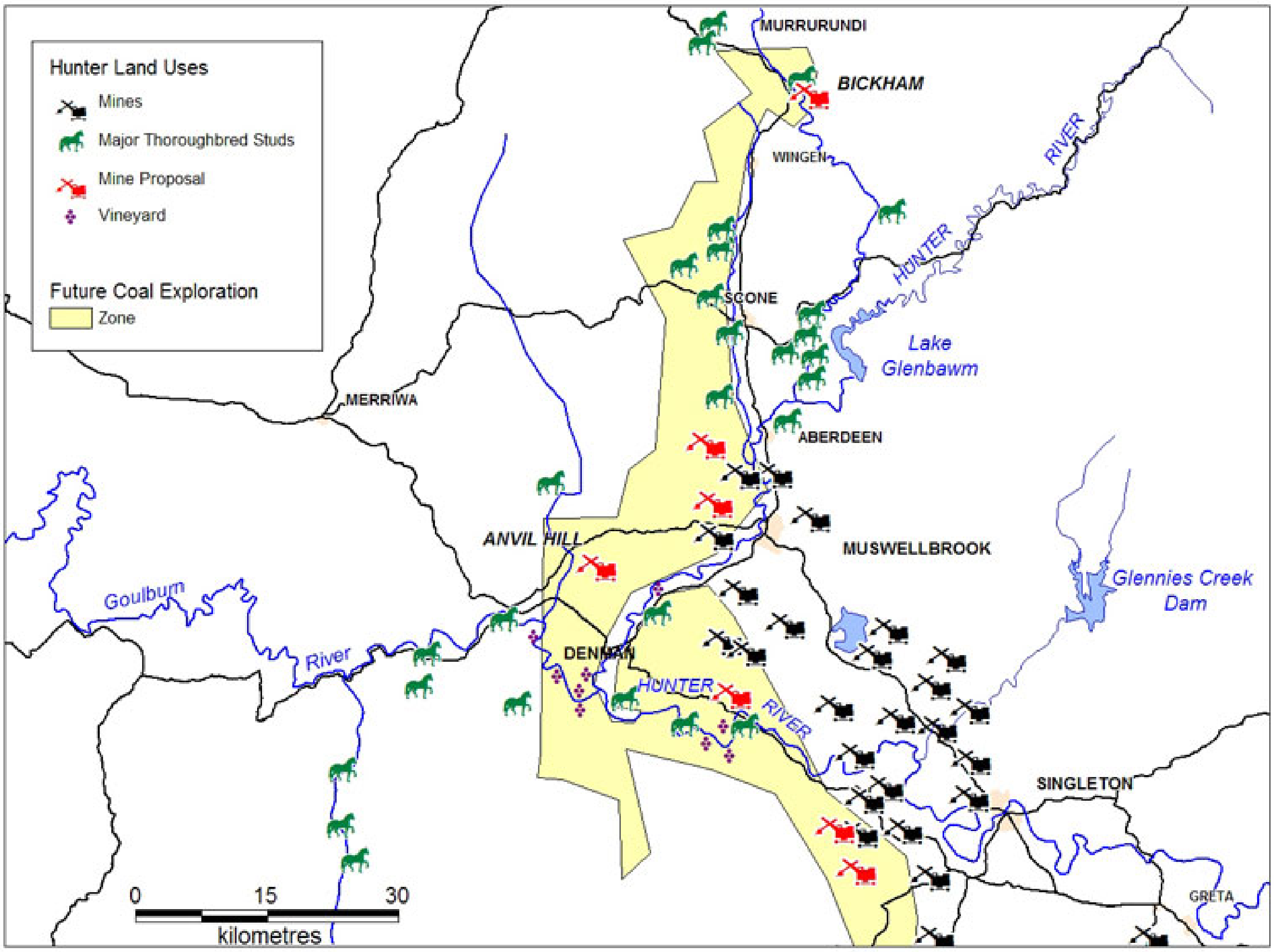
Fig. 3. Mt. Arthur mine, covering 40 km^2 of the Upper Hunter Valley (photograph courtesy of L. Rhiannon).

From 2003–2006, a transdisciplinary team of researchers from the University of Newcastle, NSW, documented human health distress in the community linked to the rapid expansion of mining over the last two decades (Connor et al. 2004, Higginbotham et al. 2006). The study recorded higher incidences of respiratory disease and depression than other rural areas of the Hunter that were not subjected to mining, confirming local residents' concerns that the coal industry was harming their health and sense of well-being (Ray 2007a, b, Thompson 2006b, Albrecht 2005). Revelations that the Hunter has the highest cancer fatality rates in New South Wales have also identified an issue of concern that requires further research (Kelly 2005).

The ecological and human health impacts of the Hunter coal industry span local and global spatial scales. Each tonne of Hunter Valley coal burnt in the Hunter Valley and in global markets generates 2.7 tonnes of CO_2 (Australian Greenhouse Office 2005). The burning of Hunter Valley coal is the largest single direct and indirect contribution of the Australian economy to global warming.

The climate change impacts from the burning of fossil fuels, including Hunter coal, are beginning to "boomerang" back on the health of the region's social–ecological system through higher average temperatures, lower rainfall, and increased frequency and severity of bushfires and storm events (Jones and Hennessy 2000, Pittock 2003, Hennessy et al. 2005, Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2007a, b). Water allocations to agriculture, mining, power generation, and urban and environmental flows are increasingly being contested, particularly as

Fig. 4. Mines encroach on horse studs and vineyards in the Upper Hunter Valley, around the towns of Singleton and Muswellbrook (Rey-Lescure 2007, Ecosystem Health Research Group, University of Newcastle).



farmers find their businesses threatened by loss of water to mining and coal-fired power generation (Newell 2005, Ray 2005b, Frew 2006a, b, Thompson 2006a, Upper Hunter Winemakers 2007). In short, there are multiple threats to the ecosystem and social health of the Hunter Valley.

Community support is a key controlling variable for the social license of the coal industry to operate and expand in the Hunter Valley. Local opinion surveys conducted by the HVRF found that 39% of residents of the Upper Hunter heartland of the coal industry thought the costs of the coal industry for the Hunter Region outweighed the benefits, up from 32% in 2005 (HVRF 2007b: page 7). According to the surveys, people in the 18–24 years age group strongly disagreed with the proposition that the benefits of coal mining outweighed the costs (HVRF 2007b: page 4).

The Hunter Valley is one of the three major thoroughbred horse breeding regions of the world. In 2007, the politically and economically powerful Upper Hunter Thoroughbred Breeders made the very significant declaration that the impacts of the coal industry threatened the sustainability of their own industry, stating:

> *The scale of proposed expansion of new coal mines in the Upper Hunter threatens prime agricultural land, jeopardizes hundreds of millions of dollars of investments, the jobs of thousands of people and the rural quality of the Region... [Our organization] calls for:*

- a moratorium on new mines in the Hunter
- a cap on coal exports from the Hunter Region
- an inquiry into the impacts of the coal industry on the long-term environmental, economic and social sustainability of the Hunter and other industries.

(Hunter Valley Thoroughbred Horsebreeders Association Inc. et al. 2007: page 2.)

Social movements, such as the one emerging around coal and climate change in the Hunter Valley, develop through eight stages, from initial raising of concern, through to gaining popular attention and political support, to a point where the concerns and values of the movement are widely accepted in the community and the moral authority of powerholders and decision makers resisting the values of the movement collapses. The social movement for a Post-Carbon Society may well have reached Stage 4 of Moyer's eight stages, a stage he calls "Take Off," in which the problem is firmly on the social and political agenda and around 40% of the public oppose current policies and conditions (Moyer et al. 2001).

"Take Off" is usually catalyzed by a trigger event that shows the public that current policies and events violate widely held values. Take Off in the Hunter Valley may have been reached when the coal ship the "Pasha Bulker" ran aground on Newcastle's Nobbys Beach during fierce storms in June 2007, while waiting offshore to be loaded with Hunter Valley coal. The feedback loops between Hunter Valley coal and climate change were very much in the public's mind as communities recovered from widespread stormwater and flood damage, and were humorously depicted in the cartoon from the Newcastle Herald (Fig. 5)

CROSS-SCALE LINKAGES, RESILIENCE AND TRANSFORMATION

Indications of stress within the Hunter Valley's ecological and human social systems described in the previous sections indicate growing pressures for transformation within these linked systems. The system's capacity to absorb disturbance and reorganize while undergoing change and still retain essentially the same function, structure, identity, and feedbacks is its resilience (Walker et al. 2004).

A system may appear to be resilient and sustainable when it is in fact not. The apparent resilience and sustainability of the Hunter Valley's social–ecological system is likely to prove illusory if the ecological, political, economic, or cultural props that hold it in place are removed.

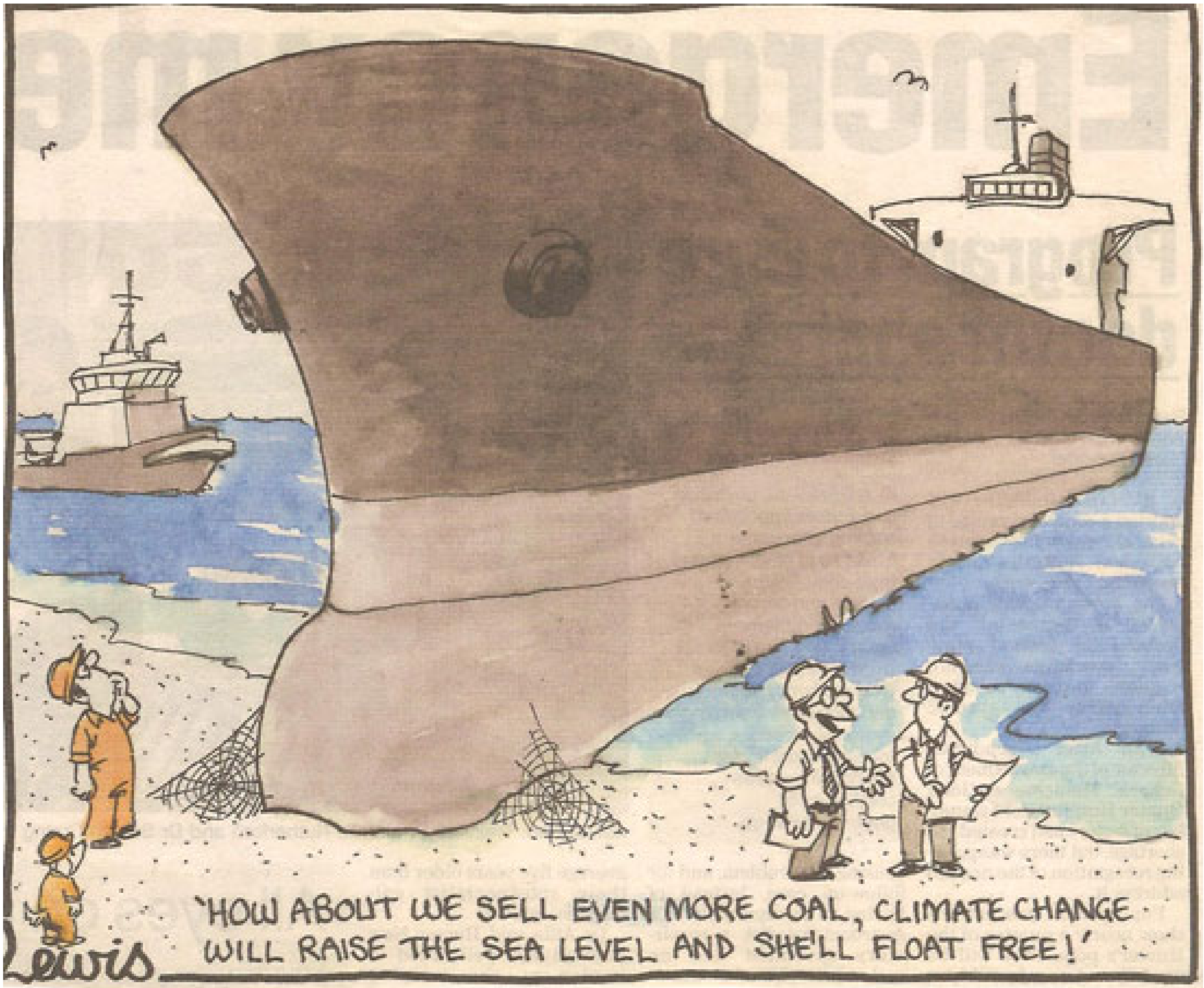
The Hunter Valley is vulnerable on two counts; the mining process harms local ecosystem and social health and diversity, thereby weakening capacity to respond to external threats and emerging opportunities; and a community whose economy depends on coal may be left marginalized and impoverished as global energy systems move to clean, renewable energy.

The Carbon Valley scenario is being buffeted by many variables that are beginning to spin out of control of those trying to maintain the resilience of the current system—ecosystem health, human health, energy markets, political processes and other features that have controlled the system across scales of space and time.

If thresholds of controlling variables are crossed there can be a collapse of apparently healthy ecosystems, financial institutions, political regimes, or technologies. Sometimes controlling variables cross thresholds together and a cascading effect producing sudden and unpredictable regime shifts follows (Scheffer et al. 2001, Gallopin 2002, Kinzig et al. 2006, Walker et al. 2006). Critical thresholds maintaining the apparent resilience and sustainability of the Hunter Valley may soon be crossed if a price on carbon emissions undermines the economic advantage of coal, if river health collapses, if political support for new mines is withdrawn.

Climate change hot spots, like the Hunter Valley, need to reduce vulnerability by developing adaptive capacity to respond to climate change threats (Adger et al. 2005, Adger 2006).

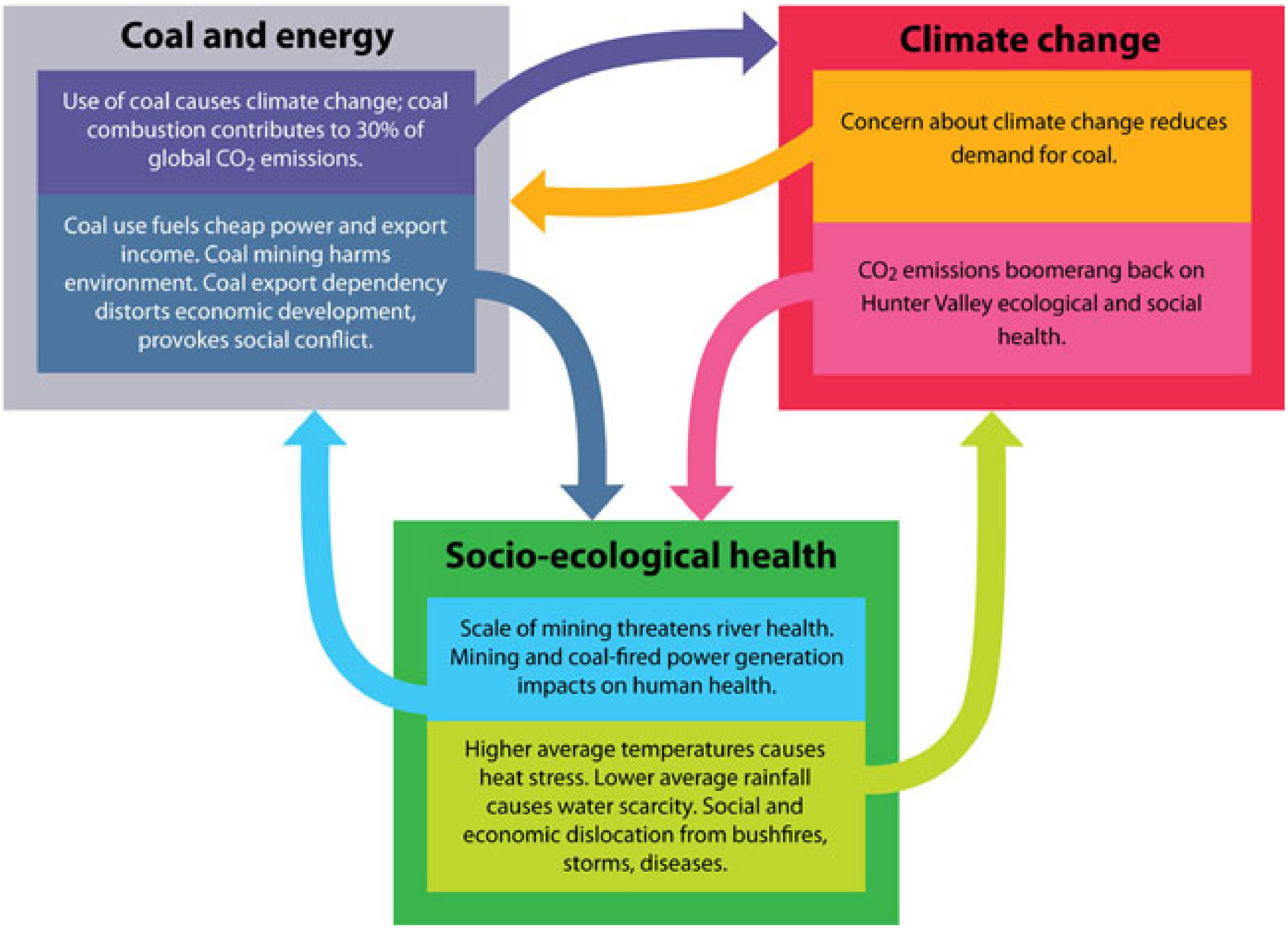
Fig. 5. Feedback loops between Hunter Valley coal and climate change in cartoon form (Cartoon courtesy of Peter Lewis and The Newcastle Herald, June 2007).



Identifying and predicting the influence of feedback mechanisms is critical for building adaptive capacity, and managing resilience and the transformability of ecological and human social systems (Walker et al. 2004, Walker and Salt 2006). The links and feedback between coal and climate change that wield significant influence on the Hunter Valley's socioecosystems, and therefore need to be managed, are depicted in Fig. 6.

Many human social and economic systems harm ecosystem health and social well-being. Chinese occupation of Tibet is arguably an example. The collapse of such a system may be a positive evolutionary trajectory—although it is desirable that this "collapse" occurs through a process that minimizes chaos and human hardship. This author believes the evolution of the Hunter Valley from its current Carbon Valley status to a Post-Carbon Society will be an evolution toward greater

Fig. 6. Links and feedback between systems influencing the evolution of the Hunter Valley socioecosystems.



ecological and social health and sustainability, and will more likely be less traumatic if the costs and benefits of change are equitably shared across the affected communities through a just transition process in which vulnerable workers and communities are assisted through public investment in income support, retraining and education, and alternative industry development (Evans 2008).

ADAPTIVE CYCLES AND CROSS-SCALE INTERACTIONS

The Hunter Valley's ecological and social systems are nested within other larger ecological and social systems operating at regional, continental, and global scales: a panarchy (Gunderson and Holling 2002).

Within the panarchy, small, local, fast-responding systems and large, global, slow-responding systems affect one another through cross-scale feedback processes. Disturbances work within and across all scales of the panarchy, and if strong enough, they can jeopardize the stability of a system. Disturbances to ecosystem and social health at the smallest scale can have a bottom-up influence on larger systems especially when multiple revolts from smaller systems destabilize the apparent stability of a larger system, such as multiple social and ecological crises threatening the structure of political or economic systems or dominant technologies (such as fossil fuel-based power generation systems).

Disturbances at the larger scale can have a top-down influence on smaller systems. Smaller, nested systems of the panarchy reorganize under the influence of the larger systems. The influences from these systems, the “memories,” can have ecological and/or social dimensions. Ecological memories such as topography, remnant populations, and seed banks may influence the reorganization of a system following disturbance, e.g., the colonization of a region in response to changing environmental conditions caused by climate change. Social memories such as local sense of place and indigenous and non-indigenous historical memories and local knowledge may inform the character of emergent societies responding to crisis.

Figure 7 shows how the Hunter Valley’s social–ecological system, including its coal industry, is nested within larger systems— global energy markets and the global climate. It also shows the process of intra-system pressures that influence the evolution of systems at different scales, labeled “revolt” and “remembering” (Holling 1986).

Although the largest system, the global climate, is the slowest-moving system, it is now the most powerful driver of the evolution of the intermediate system—the global energy markets, and the smallest system—the Hunter Valley. The diagram shows just three systems in the panarchy, but other social–ecological systems (including other coal and energy production regions in Indonesia, China, USA, and elsewhere, deforestation, agriculture, transport systems to name just a few) also influence, and in turn are influenced by, the larger systems.

Complex adaptive systems can be described as evolving through four phases of transformation: conservation or climax phase (K), release or collapse phase (Ω), reorganization or renewal phase (α), and exploitation or consolidation phase (r), toward a new conservation or climax phase (K2) (Holling 1986). This model is a useful tool for describing the potential evolution of the panarchy in which the Hunter Valley is situated.

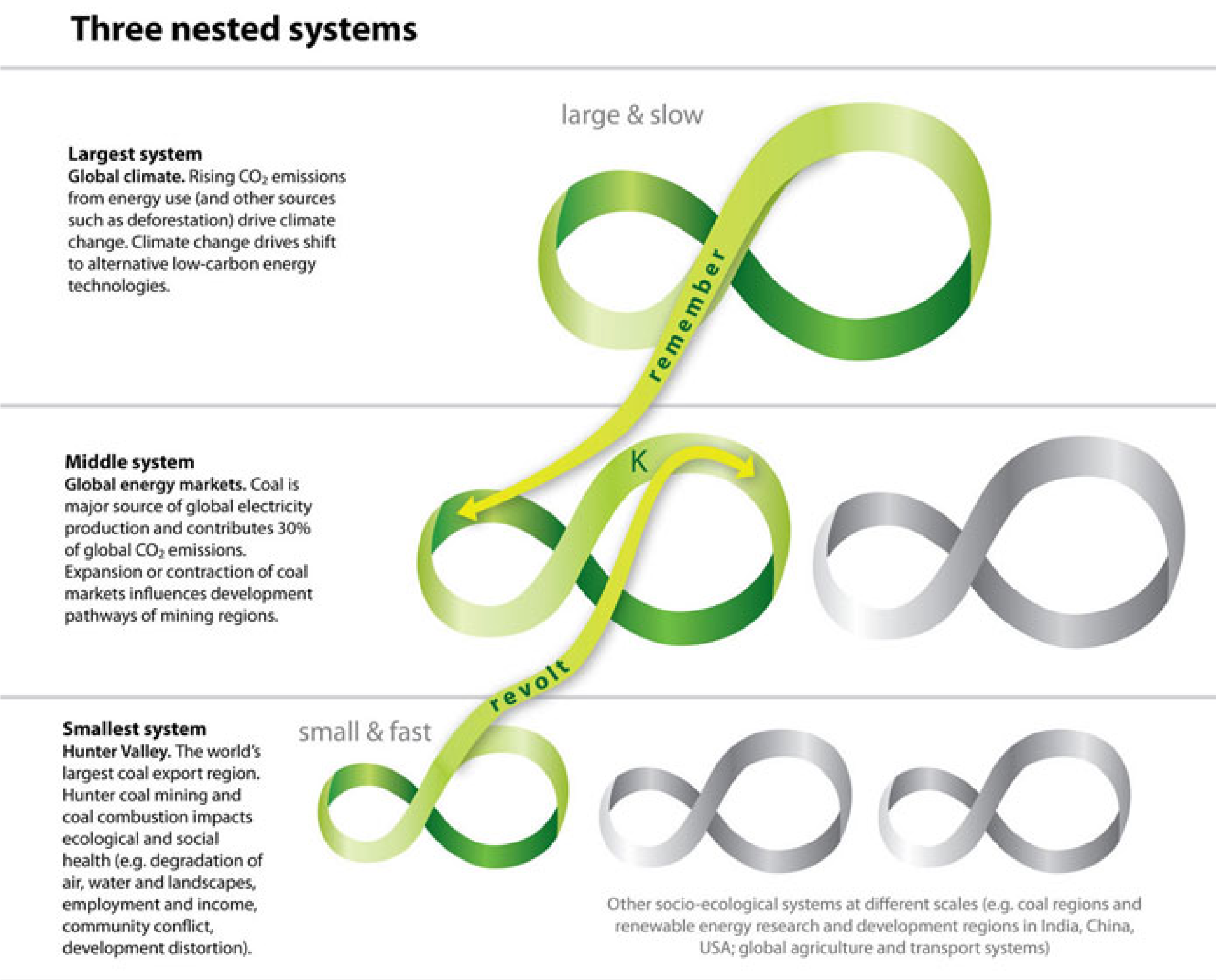
Figure 8 describes a possible evolution of the Hunter Valley, the smallest-scale system within the panarchy, through the four phases from Carbon Valley to a Post-Carbon Society. The diagram depicts a CAS of linked ecosystems and human communities from pre-colonial indigenous society into the current capitalist agricultural and industrial society, in which the contemporary coal industry is a dominant economic activity. The diagram identifies a potential transformation that may occur over the next few decades.

Social–ecological systems are systems of ecosystems and humans co-evolving. Figure 8 shows the indigenous-dominated social–ecological system as a conservation (K) phase of the Hunter Valley CAS that lasted tens of thousands of years. The advent of British colonization and the subsequent large-scale clearing for agriculture, mining, and urban settlement coincided temporally and spatially with displacement of indigenous people from their lands and loss of indigenous social–ecological relationships. These impacts created sufficient disturbance to drive the system into the release (Ω) phase.

Human–human and human–ecosystem relationships changed dramatically following colonization and establishment of the modern industrial economy. Previously coevolving and relatively sustainable ecosystems and indigenous human social systems have, over a relatively short time, been transformed to the current situation marked by linked and growing ecosystem–human health distress (described in the previous section). The Hunter coal industry is key attractor in this current system. The current Carbon Valley scenario is part of this 250-year phase in the Hunter Valley’s evolutionary cycle, the release phase (Ω). The collapse is well advanced but not yet complete. It is a relatively short phase compared with the previous K phase.

As collapse of local ecosystem and social health becomes more acute, contestation for a more sustainable Hunter Valley socioecosystem will drive the evolution of the Hunter Valley’s social–ecological systems toward a new phase, reorganization (α), which will see the emergence of

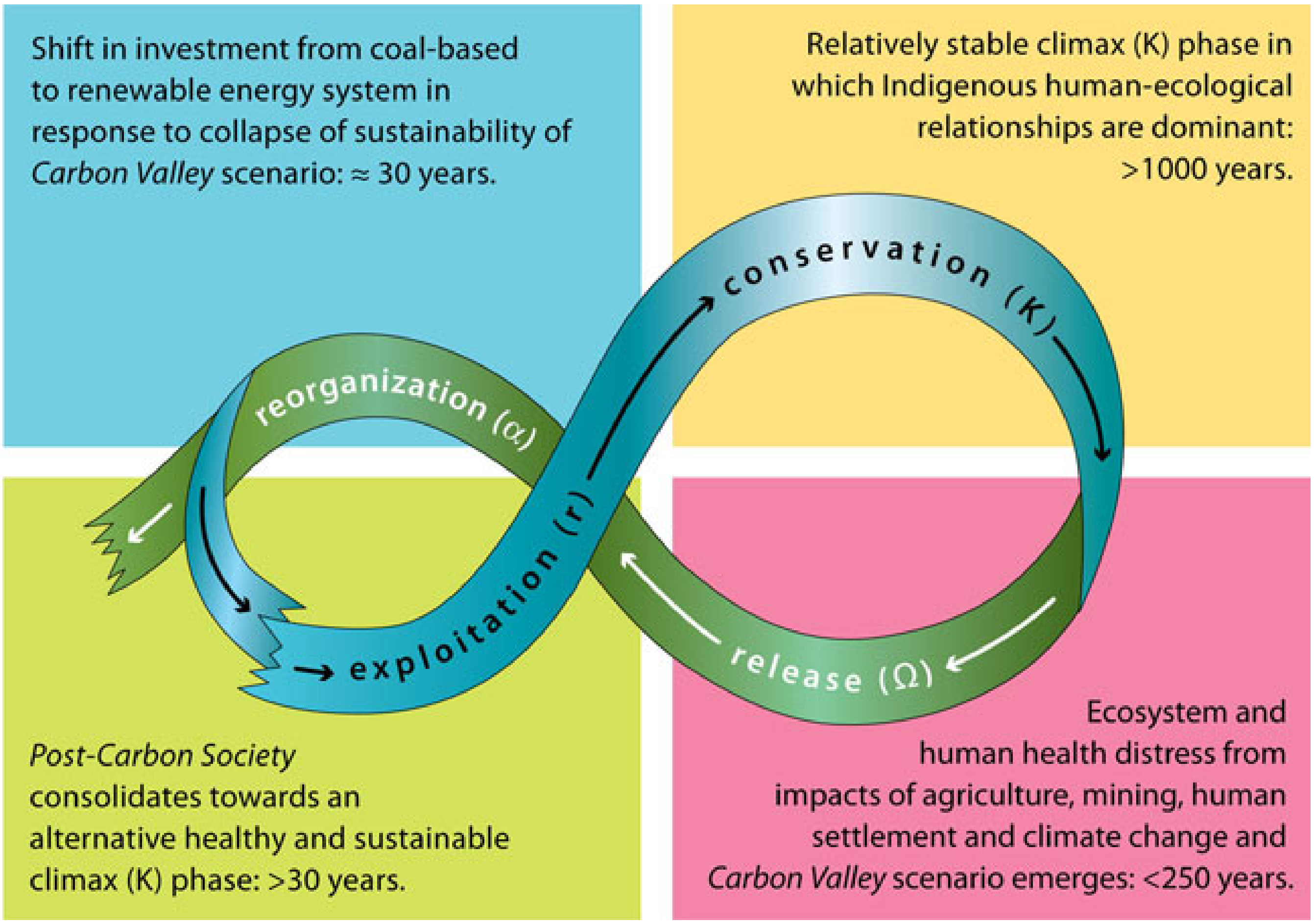
Fig. 7. The Hunter Valley panarchy.



an alternative healthier social–ecological system, a Post-Carbon Society. The reorganization may see new human–ecological relationships emerge, including more ecologically sustainable agricultural, manufacturing, and urban development. In this scenario, investment shifts from coal-fired power to renewable energy systems, coal mines are phased out, and ecosystem health begins to be restored. This phase is likely to be relatively more rapid than the previous phases, perhaps spanning 30–50 years and hopefully beginning soon.

The new ecological and social relationships of a Post-Carbon Society become institutionalized and consolidated as the system moves into the exploitation (r) phase. This phase will take at least three decades as coal-dependency peaks around 2020 and greenhouse gas emissions fall to 60%–

Fig. 8. Potential stages in the complex adaptive cycle of the Hunter Valley to a Post-Carbon Society (adapted from Gunderson and Holling 2002).



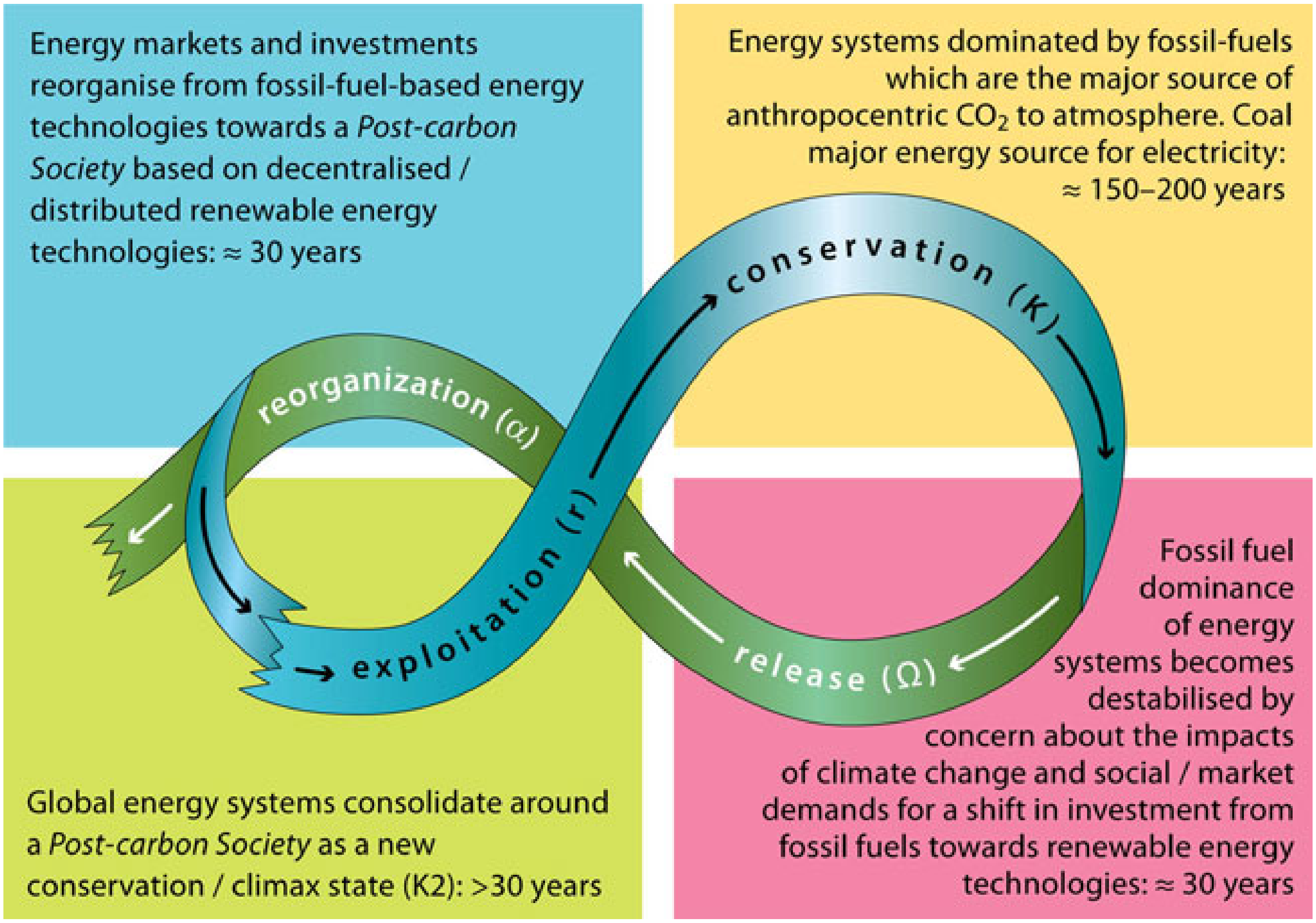
90% of 2000 emissions by 2050, as recommended by the Garnaut Report to the Australian national and state governments (Garnaut 2008). A new conservation phase (K2) will then emerge, in which the Hunter Valley again has human settlements and economic activities compatible with sustainability.

The potential reorganization of the system will emerge from using the ecosystem and human capital and services that become more available as natural, human, and financial resources currently locked-up in the Carbon Valley economy are released into new investments. Innovation will drive the form of social and economic development in the reorganization.

The evolution of the Hunter Valley is influenced by internal and external disturbances. Disturbances from global energy markets to which the Hunter economy is linked will drive the reorganization phase of the Hunter social–ecological system. The potential transformation of the second level of the panarchy, the global energy system, from fossil fuels to a Post-Carbon Society, will also be influenced by internal and external disturbances. A potential evolutionary transformation is described in Fig. 9.

In this iteration of the panarchy, the current fossil fuel-dominated energy system is the conservation (K) phase. This fossil-fuel-based energy system is

Fig. 9. Potential stages in the complex adaptive cycle of global energy markets to a Post-Carbon Society (adapted from Gunderson and Holling 2002).



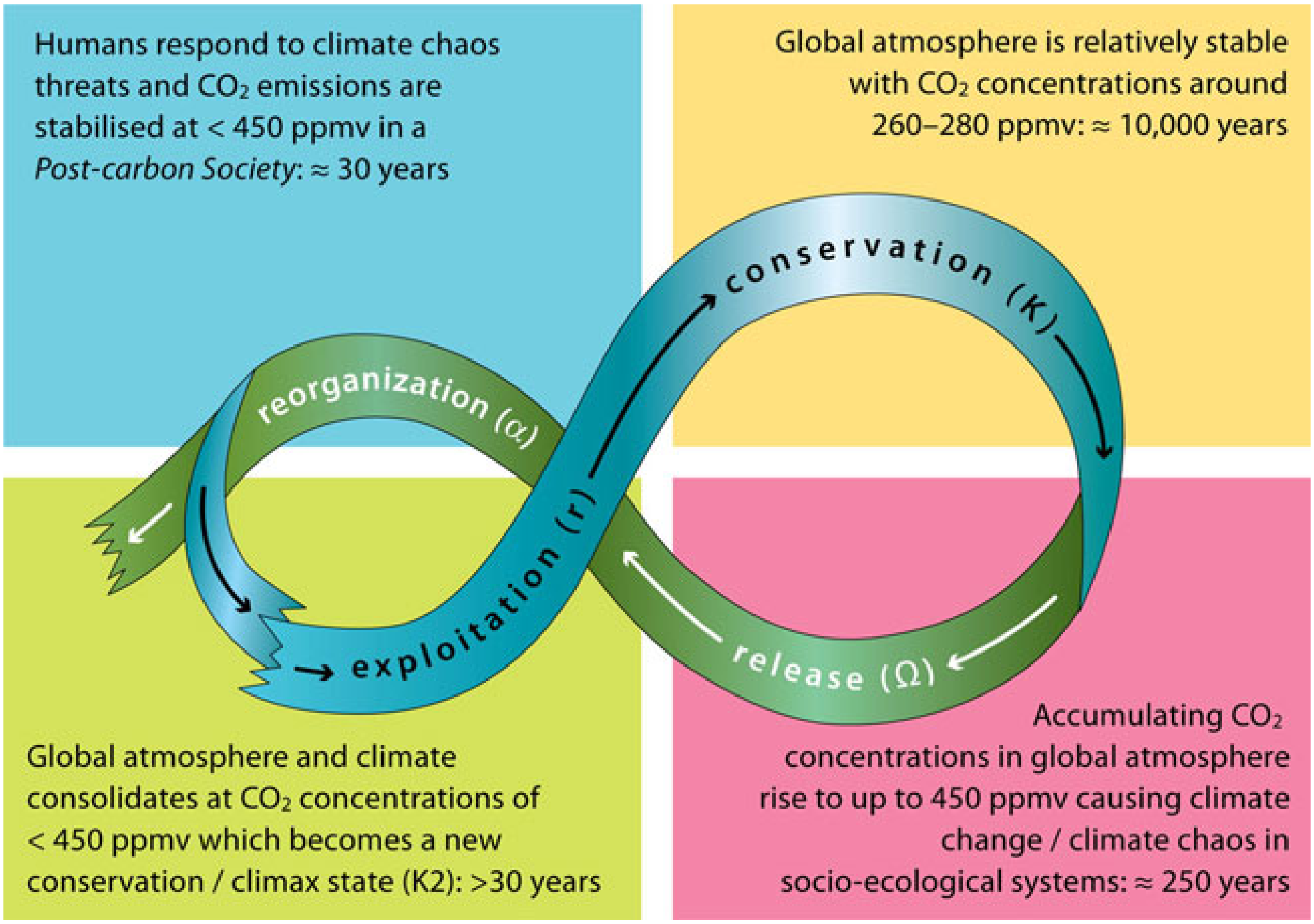
starting to collapse (release) as global concerns about climate change grow and new political, regulatory, and market mechanisms begin to constrain the cost advantage of fossil fuels. The dominance of coal in global energy markets will collapse as investment shifts to clean, renewable energy technologies. We are currently at the cusp of these release (Ω) and reorganization (α) phases.

The reorganization will see the energy markets transform as innovation and investments focus on renewable energy technologies—wind, solar, geothermal, and biomass. As the most dynamic of these technologies take off, low-emissions markets will consolidate around them in the exploitation phase, leading to their institutionalization in the new conservation phase (K2) that emerges—a Post-Carbon Society.

The potential technologies of the Post-Carbon Society will emerge from the "wealth" of the system that is released as investment and research capacity currently focused on fossil fuels become available to alternative technologies.

The consolidation of a Post-Carbon Society scenario around particular technologies is being debated and is politically contested terrain. The coal industry proposes that investment in carbon capture and storage and "clean coal" technologies will

Fig. 10. Potential stages in the complex adaptive cycle of the global climate system in a Post-Carbon Society (adapted from Gunderson and Holling 2002).



maintain a place for coal in the reorganization around a low-carbon economy. The International Energy Agency (IEA 2005) projects a big on-going role for coal in the global energy future. They predict a 30% increase in demand for coal by 2030.

On the other hand, international environmental organizations such as Greenpeace and the World Wildlife Fund (WWF) suggest that coal demand will peak by 2020 and then steadily decline as investment shifts to energy efficiency and renewable energy technologies (Teske 2007, WWF 2007). Critics suggest that the severity of climate change disturbances (the collapse of the K phase in the largest system, the global climate) will drive the need for rapid change in the reorganization (α) phase of global energy systems, and that clean coal and carbon capture and storage technologies are likely to be too little too late and too costly to have a major role in a clean energy future (Saddler et al. 2004, Diesendorf 2006).

The potential transformation of the largest system, the global climate system, through phases of the adaptive cycle is described below (Figure 10). The scenario identifies that the relatively stable global atmosphere of the last 10 000 years—the conservation (K) phase—is collapsing as greenhouse gas emissions have risen over the last 250 years. We are currently living in a release (Ω) phase of the evolutionary cycle of the global climate system as CO_2 emissions concentrate at around 400 parts per million by volume (ppmv) with resulting global warming. These emissions come from multiple sources in many smaller nested systems, including fossil fuel-based industrial societies around the world, as well as from deforestation, transport, and other sources (Intergovernmental Panel on Climate Change (IPCC) 2007a).

If CO_2 emissions stabilize in responses to climate change threats the system will stop collapsing and could move into a new reorganization (α) phase where the global atmosphere and climate begin to stabilize. The current release phase of accumulation of CO_2 and threatening climate chaos will continue for decades yet, and the reorganization phase will continue for most of the 21st century.

A new state of climate equilibrium will emerge during the exploitation phase, hopefully below the 450 ppmv level of CO_2 identified by scientists as the maximum level of CO_2 concentration allowable to prevent climate chaos (IPCC 2007b). The system would then enter a new conservation (K2) phase in which the atmosphere stabilizes at this level (or lower).

CONCLUSION: RESILIENCE AND THE POTENTIAL FOR TRANSFORMATION OF THE HUNTER VALLEY

The scale of threats to ecological and social sustainability posed by large-scale disturbance of previously relatively sustainable human and ecological and human–social systems of the Hunter Valley has moved the region's social–ecological system into a crisis state. The region's massive coal industry is a major contemporary contributor to this crisis. Fossil fuel use is also a major contributor to global warming and climate change with impacts at local and global scales. The scale of local ecological and human health threats and of global warming suggests an urgent need to snap out of these crises and begin the process of reorganization and consolidation of alternative human–ecological relationships, of which more ecologically and socially sustainable economies are a critical part.

At the level of the Hunter Valley, this transformation would be from the region's current Carbon Valley status toward a Post-Carbon Society.

Understanding vulnerability, resilience, and how to build adaptive capacity is critical for managing for sustainability. The resilience of the Carbon Valley scenario relies on the maintenance of the current basin of attraction, which has promoted the Hunter Valley's coal industry—fossil-fuel-based industrial economies, globalized energy markets, political willingness to offset environmental protection for export income, etc.

The Post-Carbon Society scenario would emerge from the strengthening influences that would weaken coal as a dominant energy source, including internalization of the environmental and social costs of coal, and shifting research and investment to renewable energy sources, curbing resource consumption by human societies, and promoting the equity and precautionary principles of sustainability.

The drivers of evolution of the linked ecological and human social systems discussed in this paper include current and threatened collapses in ecological services, with resulting dislocation and conflict in human societies. They will include political responses to these crises, such as the international treaties on climate change and international clean energy technology transfer. A local, national, and international governance, regulatory and market environment that sets and operates within scientifically determined environmental limits and that internalizes the full environmental and social costs of commodities is vital.

The transformation of the Hunter Valley from Carbon Valley to a Post-Carbon Society is not inevitable. The transformation is subject to intense political contestation, but it is a potential trajectory for the Hunter Valley's evolutionary cycle that could again bring the region's natural and social systems back into harmony.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol13/iss1/art39/responses/

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