Paper (II): INTRODUCING ADAPTIVE SUSTAINABLE DEVELOPMENT
- a framework for policy and planning.

SUSTAINABLE DEVELOPMENT: UNDERSTANDING & ISSUES FOR INDUSTRY
An occasional series of brief papers designed to explain key ideas and provoke dialogue.

COOPERATIVE RESEARCH CENTRE FOR COAL IN SUSTAINABLE DEVELOPMENT (CRCCSD)

> In a dynamic, changing world with an uncertain future, we cannot aim to satisfy sustainability by seeking to "leave the world as we found it in detail" but rather must aim "to leave the option or the capacity to be as well off as we are". (Robert Solow, *The Economist*, July 6, 2002).

Overview
This paper explains and advocates a shift in understanding sustainable development:

Impact reduction	⇒ ***Shift in focus*** ⇒	Improving adaptiveness

We presently assume the impact-reduction approach which, while it can lead to proactive re-design to prevent impacts arising, instead mostly focuses industry thinking on defensive 'patching' of present systems to increase efficiencies and so reduce emissions, a lose (cost) – win (environment) strategy. However this paper argues that the adaptive approach offers a number of key advantages:

- the widest, most innovative design framework for developing future industry and national strategy,
- access to high performance futures that are simultaneously economically and ecologically sustainable,
- choice of the best adaptive strategy for moving flexibly into the future so as to seize these opportunities as developments unfold.

At its best this represents a 3-way win-win outcome for industry, the environment, and the nation.

The idea is simply illustrated in examples emerging from the 'green chemistry' movement - for instance the use of volatile, toxic solvents in the production of amines, used in many pharmaceuticals, can now be replaced in important cases by solvent-free processes through use of different metal mediators, eliminating the original hazards and wastes. This illustrates a deep re-design perspective where, instead of looking to patch up the existing process (shallow re-design), one opens up the whole process to re-design, the only constraint being to still deliver the same overall service. The greater design space opened up offers opportunities to achieve production without the original (or nasty new) deficits. [See CSIRO Sustainability Network Update 24E, 2003 or http://web.chem.monash.edu/greenchem.] In this case the task is made safer, simpler, and cleaner, this represents improved industrial adaptability and a win-win for the manufacturer, the environment, human health, and the economy.

In particular, this approach opens up an opportunity to explore new options for coal as a key component in future adaptive industrial designs that also deliver high environmental performance. Consider for example the provision of cement from ground iron-making blast furnace slag (presented in Discussion Paper #1), the slag formed jointly from coke ash contributed by coal and sinter gangue contributed by iron ore. This cross-industry re-design of the smelting and cement making processes permits the same services to be provided with greatly increased economic and environmental performance. It achieves its wider design options and benefits through embedding the original coal process in a larger network, and shifting corporate identities toward a wider energy-materials services focus. Integrated coal gasification, seen as providing a feedstock to many industries, may provide the basis of another, similar example. We expect that a shift to industry networks and to more generalised corporate services identities will play important roles in re-design to achieve high sustainability futures. Moreover, carefully explored examples of these kinds set a proper framework for developing transitional energy pathways to sustainable futures and policies to achieve them. There is a lot involved in this re-orientation, abstractly summed up as follows:

Past/present ***Restrictive interpretation***		***Emerging/future*** ***Constructive interpretation***
Impact reduction ∴ Efficiency increases ∴ Lose-Win strategies ∴ Light green achievement	***Shift in focus*** Closed present Ψ open future Actual design Ψ Design potential Damage control Ψ Adaptive resources Short term means Ψ long term ends Assurance Ψ Insurance Defensive stance Ψ Constructive stance	Adaptive expansion ∴ Option increases ∴ Win-Win strategies ∴ Dark green achievement

Introduction: is green-black conflict the best way forward?

These days we are all in favour of sustainable development. But what does it really mean and what are the consequences of adopting it? This is not a minor issue for many industries, where meeting environmental standards may cost $millions and not doing so may threaten exclusion from Australia's future. For instance, use of fossil hydrocarbon fuels (oil, gas, coal), condemned as non-sustainable, is already facing the prospect of a carbon tax that will impose costly shifts in the conduct of business; government backing for a long-term purely bio-solar alternative would threaten its existence.

For many it appears obvious that adopting sustainability requires eliminating the use of fossil hydrocarbons because of their multiple negative environmental and health impacts; it needs no further argument. It is green versus black. If this is correct then the only acceptable goal of sustainable planning is their orderly replacement. And the only sensible business goal of fossil hydrocarbon industries, Australian coal-chain industries among them, is to oppose that process until finally succumbing to planetary pressure. At best this will eliminate the coal and allied industries; but it may prove unnecessarily costly and may lead to a damaging 25-year confrontational process that will weaken Australian political and economic capacity to pursue innovative technologies and sustainable development policies. At minimum we should extract from our use of non-renewable coal the benefit of transiting successfully to a sustainable future.

But, worse, what if this 'obvious' green versus black position is in fact incorrect? Suppose instead that a more adequate notion of sustainable development were to lead to a widening of policy options to include potentially valuable industrial roles for fossil hydrocarbons, both stand-alone and in bio-solar-hydrocarbon synergies. Then effort wasted in confrontation will be the least of our regrets. More regrettable - for both green and black - will have been the lost opportunities to focus on developing these more flexible, more win-win sustainable options.

In this discussion paper a notion of sustainable development will be introduced that does indeed provide for expanded design horizons. It will be explained what it is, why it is more adequate, and what policy-making tools support it. It opens up new opportunities and challenges for fossil hydrocarbon industries, Australian coal-chain industries among them, in transiting to, and contributing to, sustainability.

We must not allow patching the current system to blind us to more innovative ways to achieve the same services without the deficits, nor thereby allow the current unsustainability of coal use to blind us to a wider range of future industrial design options where coal may play a key role in achieving high sustainability.

This is a work of understanding in progress. How wide and rich we come to decide the opportunities for hydrocarbons are will depend on many factors, important among them: (i) what we come to understand about the impact of hydrocarbons on Australia's future adaptive potential, both industrial and ecological, (ii) the research and development outcomes for a wide range of innovative technologies now under investigation, (iii) the innovativeness (or otherwise) of our future business and planning environment, and (iv) the socio-political national goals we come to embrace. Here we set out the framework.

I. The current impact-reduction concept of sustainable development.

The need to redress our serious environmental problems - habitat loss, soil erosion and salination, climate change, pest introduction, etc. – compounded by non-renewable resource depletion, is now widely acknowledged. The problems were, and are, produced by galloping economic expansion often made worse by arrogantly optimistic and narrowly self-interested exploitation. So it is not surprising that we find ourselves with an environmental movement focused on blocking careless industrial and settlement expansion, removing ecologically damaging practices, and generally preaching restraint and simplicity. This focus extends in a natural way to socio-economic 'environmental' problems such as urban air pollution, industrial accidents and poverty traps, the same values recommending reducing pollution, injury and inequity. The approach drew the support of world-scale studies and proposals such as those by the Club of Rome (*Limits to Growth*, 1972).

It was from this context that the idea of sustainable development emerged and it has continued to share this orientation. The current wide-spread assumption is that sustainability means curbing and shaping our economy so as to not disturb the natural environment and not damage ourselves, and so focuses on decreasing all harmful wastes, land alienation and so on. Ways to do all this, while still providing a functioning economy that meets human needs, are what constitute sustainable development. When the UN (Brundtland) Commission defined sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (*Our Common Future*, 1987), this is how it was understood.

In this case the natural way to measure progress toward sustainability is to measure decreases in emissions of harmful wastes, exploitation of resources, industrial accidents and so on. Measures of each of these yield the many convenient key performance indicators of sustainability now widely used. Adding together all the negative ecological impacts provides the classic 'ecological footprint' measure of the nett ecological demands made by our lifestyle. Reducing this footprint is taken as increasing sustainability.

Both exploitation and wastes are reduced by reducing through-put and, if customers are to remain satisfied, that can only mean increased production efficiencies. So this is how coal-chain industries can claim green credentials under this approach. This aim represents one arm of current CCSD research. Acquiring increased efficiency is an investment cost to industry but a win for the environment; only where it yields decreased unit prices is it a win-win situation for both. Key performance indicators readily follow and life cycle costing analysis (also part of CCSD) is a good way to measure them. That is where we are now.

However, and recalling the green chemistry example above, environmentalists may instead translate sustainability into replacing hydrocarbons with other resources entirely, so that the same social services (warmth, transport, etc.) are realised with still less environmental impact. What this possibility shows is that improving present process efficiencies alone may at best turn out to be a light green effort that will provide only superficial sustainability improvements. It may not ultimately be enough to claim deep green credentials for black industry and to access much more profound increases in productivity.

This raises the sustainability issue from increasing current efficiencies (light green) to choosing the overall superior design to our eco-economic system (deep green). And posing the issue at this level allows us to equally include the matching deep green issue of modifying the initial demand for energy and materials services through system re-design. Here too the goal must be to show that black is a key part of deep green - and so overall (though not painlessly) this too can be a win-win development for environment, industry and public.

> Claiming deeper green for coal use requires showing that hydrocarbons have a distinctive role to play in the energy-materials supply of the overall industrial system design that offers the greatest sustainability advantages. This involves moving beyond a simple focus on impacts, and beyond a corresponding reactive, self-defensive stance to a more pro-active overall design stance.

II. Re-orienting with fire: shifting focus from current state to future adaptation.

Bushfires destroy many living things. So for many years our management of natural areas aimed to eliminate them. The paradoxical result was that we did more harm than good to the environment, and ourselves, because the build-up of litter meant that some species could not grow, and when a fire did occur it was much more destructive. Now we understand that each ecology will have a complex natural fire regime to which its species are adapted and which, despite its recurring destructiveness, actually helps to preserve environmental productivity and capacity to adapt.

Analogously, while not disturbing the environment is in itself a good idea, there are also basic problems with adopting this approach. First, in its pure form it is literally impossible. Every species, every creature, has an unavoidable impact on its environment. And even with restraint humans could not realise much of their enormous potential - their cities, science and arts, international justice, and so on - if they did not make a substantial impact. Nor need impact be all bad. We have begun to appreciate that long term aboriginal use of 'fire stick farming' has often only modified the natural fire regimes while contributing to productivity and adaptiveness. So the real issue in the long run is which impacts to selectively winnow, rather than attempting blanket avoidance of all impacts.

Second, far from being environmentally alien, change is in fact endemic to the environment. Highly dynamic systems like ecologies are self-altering, constantly engaged in intrinsic processes of creative destruction and construction through ecological succession (via fires, siltation, species competition, etc.) and evolutionary change. Moreover their geo-climatic environment is also just as dynamic, from El Nino, earthquakes and volcanoes to larger weather shifts on many different timescales, all these also inducing continual environmental change. It cannot be our problem to stabilise our environment, that would be highly unnatural - indeed, much of our environment's capacity to cope with change, crucial to its long term survival, is itself only developed through undergoing repeated changes.

All this is even more true of our economy. It is also constantly engaged in intrinsic processes of creative destruction and construction as old firms disappear and new enterprises arise, brought about by technological and institutional change. These changes are largely produced by the very market dynamics that the new enterprises will in their turn transform. And here our basic attitude is that this is a good thing overall since it brings expanded opportunities and wealth and, like ecosystems, firms emerge more able to deal with change from having undergone it. We do have reservations, about wasteful market excesses, hurting people through poorly managed change, and the like, but the point is that we are not tempted by these issues to think that economic change is basically wrong and to try to stop it. Rather the problem is how to manage change more wisely.

Rather than simply reducing impacts as the focus of sustainability (even if doing that will often be a practical outcome), we need to re-focus sustainability around understanding, sustaining and managing the change processes central to our ecological and economic systems. Only this conception of sustainability can offer an appropriate basis for sustainable re-design of Australian industry, and society.

> The sustainability of coal use should be focused on its nett positive contribution to successfully sustaining and managing ecological and economic transformation.

III. Adaptiveness, the heart of managing change.

What is involved in successfully sustaining and managing change? Start with the most straightforward case. Independently of how well we can cope with it, if we know that a specific change is coming, and when and where, then our problem is simply one of identifying and assembling our best available response. *Lesson 1: all effective response to change requires having available real, materially actualised response options.*

Recall, for instance, the case used in Discussion Paper #1 where in April 2002 the sole Australian automobile muffler manufacturer for the South Australian automobile assembly lines suffered a strike. The strike shut down the assembly lines because it halted the only supply of mufflers. We saw that there were essentially two distinct ways to cope with this change, keep a stockpile of spare mufflers or use more than one supplier - whether within Australia or overseas. But to be effective, the stockpile has to be real, not just imagined. Similarly, the additional suppliers must be real, still viable when the original supplier is operating, and able to ramp up their production at short notice when it is strike-bound. Whence *Lesson 2: creating a real option requires planning, organisation and expense.*

Each real option has its limits. Suppose, e.g., that the strike had bankrupted the sole supplier. Then the stockpile option would cope only temporarily. Suppose instead that the entire muffler industry was strike-bound together because of concerted union action; then the multiple supplier option would not cope at all. Further, suppose existing muffler makers halt production because they cannot manufacture newly demanded catalytic converters, or because conversion to fuel cell powering renders them obsolete; then none of the previous real options will cope. *Lesson 3: each real option copes with only a limited range of changes; the wider and deeper the changes involved, the greater the range of real options required to ensure possessing an effective response*. This lesson applies irrespective of how much one knows about the specific changes coming: even had the muffler strike been fully predictable it would not have altered the need for a relevant real option in response.

> Viable energy industries will need real options, not just potential ones, to cope with coming technological and environmental performance changes, options wide and deep enough to furnish adaptive responses to these changes. To acquire these requires planning, organisational change and investment.

Real options provide real flexibility of response. When you have developed a suitable range of real options then you have the means to respond to a range of potential changes in ways that will keep you functioning. Conversely, you also have the capacity to deliberately generate beneficial changes, e.g. by introducing superior technology or products (cf. the green chemistry example above). Either way, whether other-generated or self-generated changes are involved, providing real options is an extension of a firm's insurance policy - extended to cover response to future changes in business conditions where insurance is inefficient or unavailable. In the language of Discussion Paper #1, real options express your adaptability (if the option is designed to accept permanent changes in order to maintain core functioning), or your resilience (if the option is designed to restore your original condition). And *your range of real options is a good measure of your adaptiveness* (i.e. of your adaptability + resilience).

So the heart of successfully sustaining and managing change is, as we learned in Discussion Paper #1, to develop the relevant adaptability, supported by relevant resilience. And, as we also learned there, having real options involves locking up resources in infrastructure, personnel skills etc. that typically remain significantly redundant until the relevant option needs to be exercised. (The muffler stockpile is the simplest example.) So having real options is inefficient in the short term. But in the longer term and wider context that takes account of the impact of change, it proves efficient.

IV. Adaptive sustainability, an emerging concept of sustainable development.

Putting sections II and III together, we arrive at the conclusion that our ecological and economic systems are highly dynamic change generating systems, so the heart of successfully sustaining and managing that change lies in their adaptability, supported by relevant resilience. The best way to provide for their future is to sustain their adaptability and resilience.

BP and Shell are investing $millions in alternative energy technologies to acquire technical expertise and organisational competence in their future deployment. They do this because they face future uncertainty about viable energy sources, technologies and uses, and this diversification provides them with requisite adaptability. They intend to be in a position to exercise as real options the profitable deployment of these technologies as the opportunity arises.

The same applies for ecosystems. When dryland Australian ecosystems carry small numbers of several species that duplicate functions of the currently dominant species, it is to provide them with real options for responding to climate change, e.g. to drought. Some of these redundant species will differ in drought tolerance, so that in drought one or more of them will breed up to replace the declining dominant species and so maintain ecosystem functioning. (Compare alternative suppliers of mufflers.) This investment in redundant species represents that ecosystem's real options, its adaptiveness. The best way to provide for the future of our ecosystems in the face of climatic, fire, pest, and human impact uncertainties is to sustain their requisite adaptability plus resilience. As just illustrated, this is what happens naturally when ecosystems become adapted to change.

This suggests the following *principle of adaptive sustainability: sustainable development is development that preserves or enhances the adaptability, plus relevant resilience, of both the ecological and economic systems*.

How does this relate to the original UN proposal, that sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs"? At first sight the two seem to clash, since earlier the UN proposal seemed to point instead to an impact reduction approach. But now let us re-consider the proposal in the light of the discussion above.

> The adaptive sustainability of energy industries will be determined by their nett positive contribution to economic and ecological adaptiveness, i.e. by the extent to which they help to provide real options to our economy and environment for successfully sustaining and managing change.

We have to make provision for preserving the capacity to satisfy future needs, that is, we have to preserve future real options for satisfying those needs. But we must in fact do this in the face of wide-ranging uncertainties, uncertainty about future values, future technologies, ecological changes, economic transformations, and so on. So we cannot simply aim at preserving specific need-satisfying resources for specific future needs. That attempt is virtually certain to fail and in doing so will likely create large unnecessary waste of scarce resources (see also below). But we have learned that in the face of uncertainty what is really required is the preservation of future adaptiveness so that future need-satisfying opportunities can be taken up. So it turns out that the UN proposal, carefully understood, supports the adaptive sustainability principle proposed here.

Although sustaining adaptiveness is still a somewhat novel way to formulate sustainability, the core idea is now emerging rapidly in many different disciplines. In the economics literature, for example, the chief vehicle of enterprise, the firm, was originally largely understood as a simple cost-reducing convenience (you only have to contract your employees once, not each time anything is to be made), but it is now coming to be seen as an adaptable organisation for responding to an uncertain set of future process and product demands as technologies, tastes and laws change. And 'industrial ecologies' of mutually trading firms are assessed not only for their efficiencies, but increasingly for the similar adaptabilities their interconnections confer. At the same time ecological analysis has increasingly focused on the importance of ecological adaptiveness (adaptability + resilience, often called simply resilience), with a world-wide 'Resilience Alliance' having emerged (see http://www.resalliance.org), and so on.

Adaptive sustainability and impact reduction.
There is, however, still a useful place for impact reduction. First, in many cases the ultimate outcome of beneficial adaptive re-design will include impact reductions. A major health and environmental advantage of the 'green chemistry' solvent-free re-design example (Overview, above) is the elimination of toxic wastes. This, along with simpler, widely used inputs and outputs and like features, contributes to increased chemical industry adaptiveness. But in achieving this it is the adaptive re-design, not the impacts per se, that is the focus. Second, in some cases impact reduction may simply be the best way to sustain adaptiveness, e.g. in many cases of land clearing where consequent habitat removal reduces adaptive biodiversity in the local ecology. (Although there is always the possibility of alternative agricultural methods, like hydroponics, to consider.)

> Sustainability and welfare are different and complementary grounds for reducing impacts.

Third, there are many cases of beneficial impact reduction presently included under the umbrella of sustainability that, while they do not belong there under the adaptive approach, remain valuable goals to pursue on welfare grounds. For instance, most negative impacts on human health, say short of pandemics and high infant mortality in poor nations, have little impact on economic or ecological adaptiveness, so under the adaptive approach there is little sustainability rationale for removing them. Nevertheless improving health remains a valuable welfare goal in itself, irrespective of any contribution to adaptive capacity, so impact reduction should be pursued on welfare grounds as a complement to achieving sustainability. Note conversely that sustaining adaptiveness involves both sustaining the future capacity to generate welfare and the regeneration of the adaptive capacity itself, while sustaining welfare per se will not necessarily do this. So adaptiveness should be the primary strategic focus, a point reinforced by the fact that, as with the green chemistry case, adaptive re-design will often prove the only way to improve both goals. (The distinction between sustainability and welfare as grounds for action, between unsustainable = degrades options and unsustainable = intolerable, is obscured under a simple impact reduction approach.)

V. How can I proceed? Adaptive sustainability policy tools.

We have seen how real adaptiveness means acquiring real options. *Real Options Analysis* provides a method for assessing the value of acquiring a real option against the cost of doing so. If, for instance, a baker wants the option of catering for weddings and like functions as well as daily supplying her shop (if she wants to be able to adapt to sudden increases in demand of that sort) then a new, larger oven may need to be installed. The obvious calculation is that of the benefit-cost difference between the nett expected profit generated by the extra catering over the oven lifetime minus the cost of acquiring the oven; if this difference is positive it is worth acquiring this expanded baking flexibility. Then compare this nett benefit with that of the next best use of the

capital, say invested in bonds over the same period, and make sure that is also positive before proceeding. This provides a way of evaluating the worth of proposals for acquiring or keeping real options for adapting to change compared to investing the same resources elsewhere.

So long as local catering demand has been researched, this is a well defined option to evaluate because all the features of the situation are already well understood. But many real options involve considerable uncertainty. BP and Shell are making anticipative investments in solar technologies so as to acquire delivery of solar-derived energy services as real options for the future, and the evaluation of their investments is essentially the same as that for the baker. But there are large uncertainties involved in planning for future times: How exactly will new energy technologies develop? What government regulations, e.g. carbon taxes, will then apply? What will consumers then want? And so on. These uncertainties mean that no simple direct cost-benefit calculations, like that for the baker, are possible. Particular options are not known in sufficient detail to calculate their costs and benefits, nor is the range of options sufficiently well known to determine what the next best investment alternative might be.

Here a second policy tool, *Robust Adaptive Strategy Analysis*, becomes valuable. In the face of uncertainties that prevent determining which detailed option is best, one can instead ask which kinds of preparation would most improve response capacity across the broadest range of circumstances? It would be sensible to focus resources on those preparations because then we are assured that, whatever specific situation turns up, we will be able to fashion a response. *The best robust adaptive strategy is one that performs as well or better than others across most or all of the widest range of relevant futures.*

For instance, suppose the baker is confident that there is lucrative local catering demand to satisfy, but is quite uncertain about its specific form. Do the customers want cocktail pies and pasties, or croissants and tarts? There may be specialist cooking equipment for each of these, but which ones to purchase? No matter, a large oven is a flexible device that can be used to bake all these and more, though perhaps needing some extra equipment (shelving, steam pans, etc.) and more complicated cooking procedures to do so. Buying an equipped oven plus suitable generic ingredients (flours, sugar, ...) then provides her with an open-ended capacity to respond successfully to a wide range of catering demands. It is a robust adaptive strategy in the face of catering demand uncertainty, arguably better than other similar strategies.

And the robustness brings with it a further bonus in addition to that of being able to successfully respond to customers' requests: given only time to bake the goods, our baker *can thereafter afford to remain uncertain about demand (within the robust range) until the orders are actually placed* since, whatever the orders are, she will be able to adapt her production to satisfy them. Postponing commitment in this way is a quite general bonus of adopting a robust adaptive strategy.

> *Real Options Analysis* provides a method for assessing the value of acquiring a real option against the cost of doing so. *Robust Adaptive Strategy Analysis* provides policies that perform as well or better than others across most or all of the widest range of relevant futures. In the face of uncertainty these strategies typically require acquisition of adaptiveness and permit delaying the development of specific responses.

Adaptiveness and learning.
Indeed, in many cases where there is deeper uncertainty about the future it will make sense to go further and postpone full commitment to even many generalised resources while learning more about the nature of the changes involved and the possibilities for robust response. This is essentially the strategy of BP and Shell; rather than trying to guess the exact future energy technology structure, they are making smaller, spread investments from which they can learn while assembling the basis for later adaptable commitments.

If she were moving into a new area, our baker might sensibly postpone commitment to even a large oven, let alone more specific equipment, while she carried out some market research and/or tested the demand profile by making small quantities of various kinds of baked goods and seeing how well they sold. Then she could tailor her equipment purchases to suit, maintaining as much flexibility as possible through use of a large oven, etc. While she might be able to correctly 'guesstimate' demand, purchase her equipment and launch immediately into full-scale business, thus maximising profits, she runs the real risk of guesstimating wrongly and wasting her scarce funds; by contrast the wait-and-learn strategy will perform at least satisfactorily across most possible catering demand profiles and perform much better than the leap-in strategy in all but the few cases which happen to guesstimate the profile nearly correctly. (Naturally, which strategy of this pair she will use will depend on her assessment of the risk involved, i.e. of the probability of guesstimating wrongly and the costs of doing so, but in cases like future energy technology uncertainty that risk must be quite high.)

A recent study of responding to threatened climate changes (Lempert/Schlesinger, "Adaptive Strategies for Climate Change", RAND Corp., 2002) illustrates the dual roles of learning and generic preparation in forming robust adaptive responses. In this case, although we have a good general idea of the kinds of changes possible (reduced rainfall, increased tropical storms, etc.) and of their kinds of consequences (reduced grain production, storm damage ...), we remain quite uncertain about the extent, speed, and destructiveness of climate change, of how amenable these are to abatement, of the required speed and cost of abatement, and of what is our actual abatement capacity. In this context, the core Kyoto Protocol strategy of reducing emissions, in addition to its

having loop-holes, looks rather like the guesstimate-and-leap-in bakery strategy. By contrast, a recent study invites us to consider a class of do-a-little-while-learning strategies, essentially strategies that put into place modest abatement measures over a decade while substantially increasing research and development into climate change and effective responses to it, then check progress against experience to decide what to do next.

The study shows that, for a class of simple quantitative model scenarios of climate change sensitivities and damages and technological-organisational abatement innovation costs, there are many quite robust adaptive strategies of this kind that perform as well or better, typically far better, than any pre-planned carbon dioxide emissions reduction strategy. It also concludes that in general lowering abatement costs is more important than increasing climate change damage as an inducement to construct effective abatement. But Kyoto is not dismissed, for they also conclude that the most important near-term feature of any climate change policy is the manner in which it encourages investment in cognitive/ informational, technological and organisational resources for abatement (not the abatement achieved). By getting us moving, Kyoto at least does this. Notice that each of these abatement resources increases our response flexibility, i.e. together they comprise our abatement adaptiveness. In short, *robust adaptive strategies recommend investment in adaptiveness as the ultimate (higher order) real option*.

> A robust adaptive coal industry strategy recommends investment in adaptiveness as the primary real option. Attempting instead to correctly guess the energy future, much less trying to control it, runs the real risk of acting wrongly and wasting scarce funds. By contrast there will be a class of iterative adapt-some/learn-more strategies that will perform at least satisfactorily across most plausible energy futures and almost everywhere perform much better than leap-in or do-nothing strategies.

VI. What comes next? Implications for coal-chain industries.

Putting sections IV and V together, we conclude that any industry is best prepared for the future by acquiring relevant real adaptive options and that it is sustainable when it contributes best among alternatives to acquiring real adaptive options for our economy and our environment.

The key coal-chain sustainability issue is the extent to which, by exploiting the properties of coal, a coal-chain energy-materials supply 'backbone' to Australian industry can deliver significant adaptabilities (not just dollars now) while abating potential damage to ecological adaptabilities (not to just current biomass). To the extent that a positive position can be established, especially relative to alternative energy backbone technologies, then to that extent coal arguably has a place in Australia's long term sustainable future. And this framework will in turn permit formulating a way forward for coal-using industries through the coming transition to sustainability.

The key sustainability strategy issue for individual coal-chain industries is the extent to which they are able to anticipatively develop real adaptive options for responding to future technological and sustainability performance changes while together being part of a rich set of real options for the wider economy + ecology. Earlier suggestions (Introduction) were that this will involve operating through integrated industrial networks to collectively deliver ranges of societal products and services while exploiting their enhanced collective adaptiveness and environmental performance. Correlatively, firms should also shift corporate identity and practice towards an appropriately wider energy-materials services focus.

> A coal-chain industry needs to develop its own adaptiveness in ways that also contribute to the overall adaptiveness of the Australian economy and ecology. This will likely involve operating through integrated industrial networks and shifting corporate identity and practice towards a wider energy-materials services focus.

In this way the two sides to adaptiveness come synergistically together. These and other features of this approach to sustainability will be explored in future discussion papers.

PROGRAM P1.2: SUSTAINABILITY DIMENSIONS AND IMPACTS
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