PROCESS INTEGRATION FOR THE SYNTHESIS OF CARBON MANAGEMENT NETWORKS.

PART 1 – CARBON CONSTRAINED ENERGY PLANNING AND EXTENSIONS

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The application of pinch analysis principles to large-scale carbon-constrained energy planning problems was first proposed in a paper by Tan and Foo (2007), which proposed a graphical approach for the allocation of energy sources to corresponding demands with specified emissions limits. This methodology has come to be known as carbon emissions pinch analysis (CEPA), and has been applied to different case studies in various countries, including China, India, Ireland, Malaysia, New Zealand, the Philippines, and the United States, among others. Furthermore, the methodology has been shown to be applicable to different sectors such as power generation or transportation; likewise, applications at different scales have been reported, ranging from the level of industrial parks to entire cities, regions or even countries. Such energy systems may be viewed as a class of carbon management networks (CMNs). In addition, the principles of CEPA have been extended to additional measures of sustainability, such as water footprint, land footprint and energy return on investment (EROI). There have also been recent attempts to generalize the methodology to consider multiple footprint indices simultaneously, while the limitations of the graphical methodology developed from pinch analysis have been addressed in part by algebraic (Foo et al., 2008), mathematical programming (Pękala et al., 2010) and graph theoretic variants (Tan et al., 2017). Key developments in this area are described in a recent review paper by Foo and Tan (2016).

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Figures

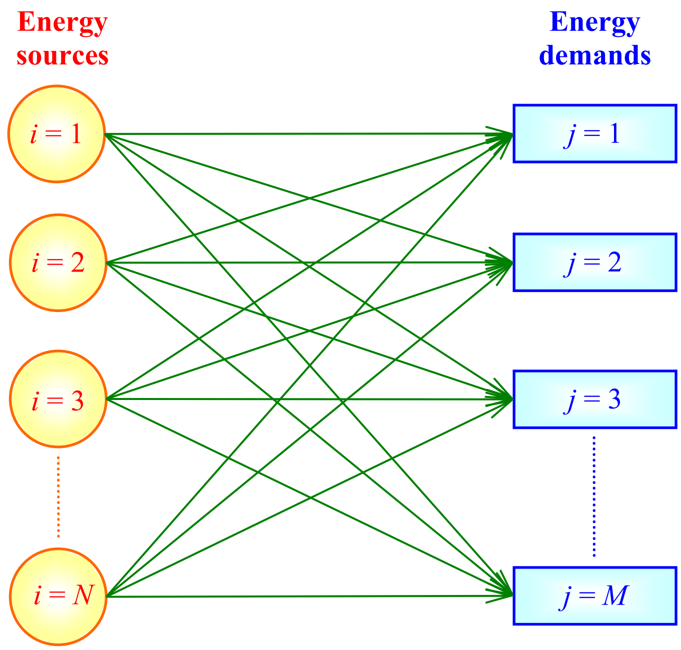

Figure 1: Sink-source representation for CEPA problem

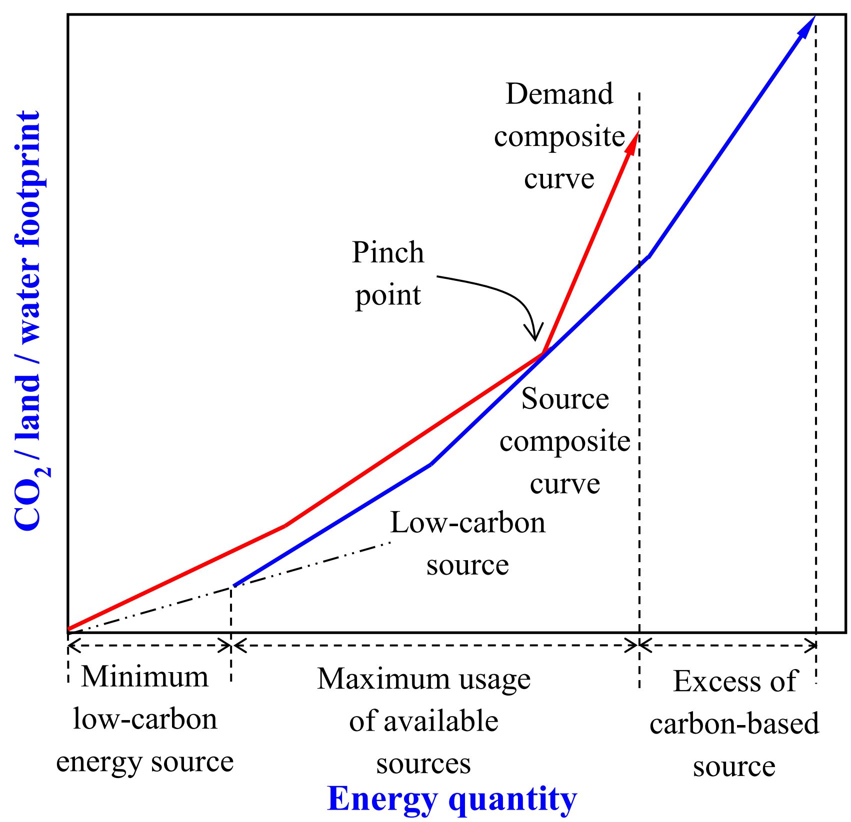

Figure 2: Energy planning composite curves for CEPA

PROCESS INTEGRATION FOR THE SYNTHESIS OF CARBON MANAGEMENT NETWORKS.

PART 2 – CARBON SEQUESTRATION AND NEGATIVE EMISSIONS SYSTEMS

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Process integration methodology has made substantial contributions to climate change mitigation through reduction of emissions that naturally results from improved energy efficiency, as well as more recent applications of principles such as *carbon emissions pinch analysis* (CEPA). Nevertheless, such contributions are inherently limited to only minimizing carbon emissions from industrial activities within thermodynamic and stoichiometric limits. The steady increase in global greenhouse gas emissions may require more drastic measures in order to ensure stabilization of atmospheric CO_2 concentration to a safe level. Process integration principles can thus be applied to the synthesis and planning of *carbon management networks* (CMNs) focusing on carbon sequestration to achieve very low, or even negative, carbon emissions. For example, both pinch analysis (Shenoy and Shenoy, 2012; Diamante et al., 2014) and mathematical programming (Tan et al., 2010; Ooi et al, 2013b) approaches have been proposed for CO_2 capture and storage (CCS) systems, where the fundamental problem is to match CO_2 point sources with appropriate storage sinks. Recent work on CO_2 utilization has led to an extension of such methods to CO_2 capture, utilization and storage (CCUS) systems (Tapia et al., 2016). Furthermore, negative emissions systems based on bioenergy with CCS (BECCS) as well as biochar-based sequestration systems have been proposed as a means to actually remove CO_2 from the atmosphere, rather than just reducing emissions (Tan, 2016; Tan et al., 2017). As such systems develop, process integration principles can continue to be developed to aid in their planning and large-scale deployment.

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Figures

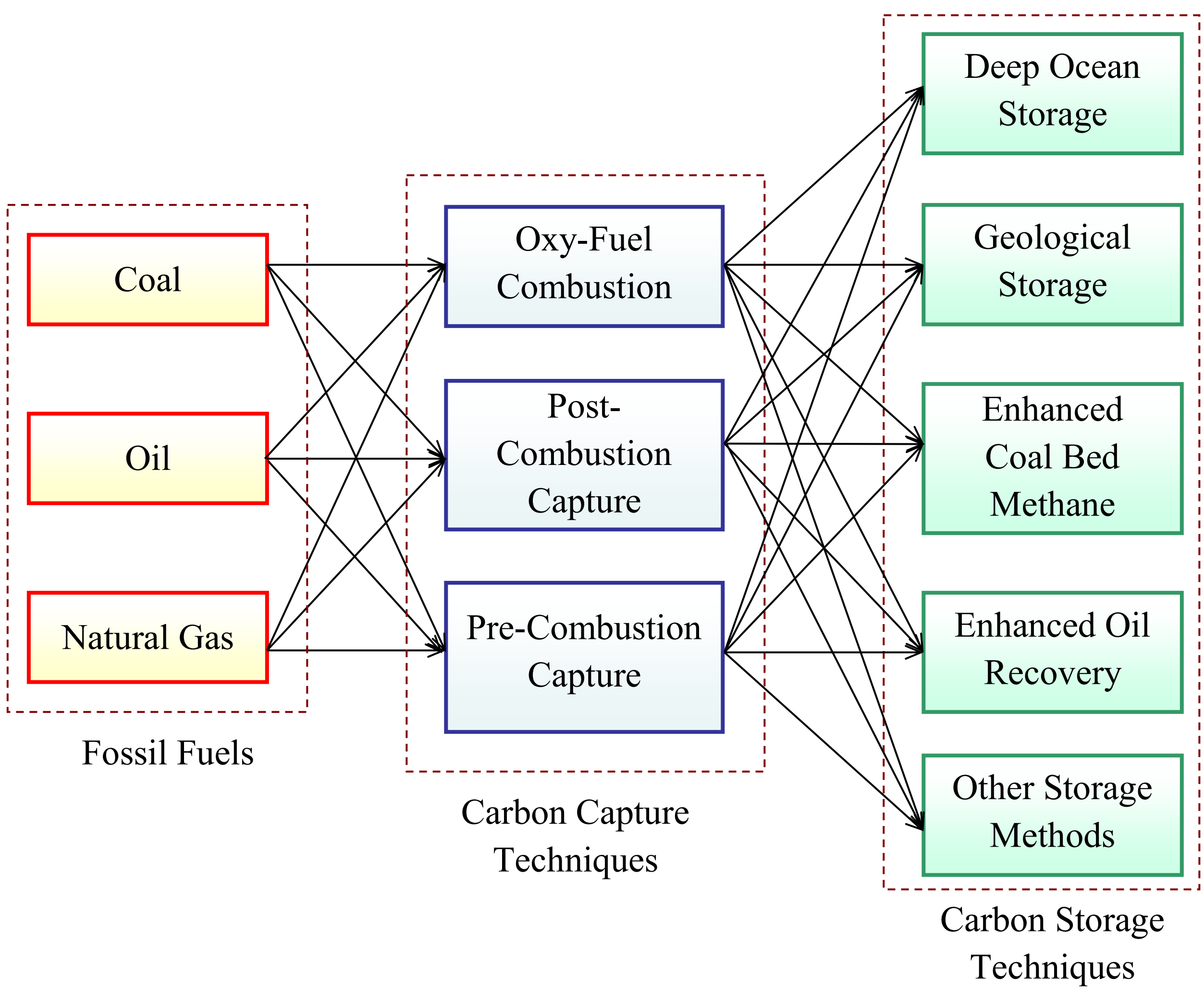

Figure 1: Superstructural representation of CCS model (Tan et al., 2010)

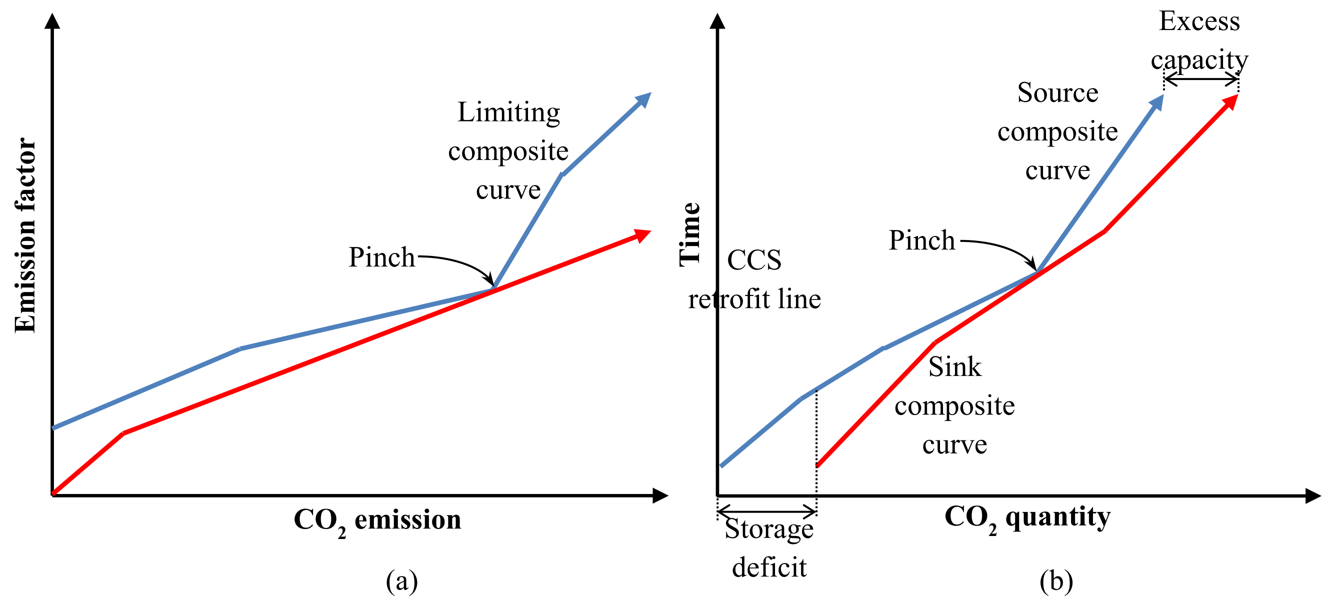

Figure 2: Composite curves for: (a) carbon capture planning (Shenoy and Shenoy, 2012); (b) carbon storage planning (Diamante et al., 2014)