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Review

People, planet and profit: Unintended consequences of legacy building materials

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ABSTRACT

Although an explosion of new building materials are being introduced into today's market, adequate up-front research into their chemical and physical properties as well as their potential health and environmental consequences is lacking. History has provided us with several examples where building materials were broadly deployed into society only to find that health and environmental problems resulted in unintended sustainability consequences. In the following paper, we use lead and asbestos as legacy building materials to show their similar historical trends and sustainability consequences. Our research findings show unintended consequences such as: increased remediation and litigation costs; adverse health effects; offshoring of related industries; and impediments to urban revitalization. As numerous new building materials enter today's market, another building material may have already been deployed, representing the next “asbestos.” This paper also proposes an alternative methodology that can be applied in a cost-effective way into existing and upcoming building materials, to minimize and prevent potential unintended consequences and create a pathway for sustainable communities. For instance, our findings show that this proposed methodology could have prevented the unintended incurred sustainability costs of approximately $272-$359 billion by investing roughly $24 million in constant 2014 U.S. dollars on up-front research into lead and asbestos.

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1. Introduction

Today's sustainability paradigm typically is conceptualized around the triple bottom line or the three pillars perspective. In 1994, John Elkington attributed the triple bottom line to the three Ps: people, profit and the planet, a sustainability term referred to as "P3" (EPA, 2015c; TheEconomist, 2009). From a sustainability perspective, the impact of our buildings and infrastructure (B&I) is stunning. B&I accounted for 16% of the gross domestic product (GDP) (USCB, 2007a). The production and manufacture of building components consumed 6 billion (10^9) tons of basic materials annually, or 40% of extracted materials in the United States (U.S.) (Yuan et al., 2012). Consumption and emissions are substantial when considering the total life cycle of commercial and residential buildings (Fig. 1): total energy use = 42% (EERE, 2012a); total electrical use = 74% (EERE, 2012b); total carbon dioxide (CO_2) emissions = 40% (EERE, 2012c); total freshwater withdrawals = 13% (Kenny et al., 2009) and non-industrial solid waste = 66% (EPA, 2009). It is also interesting to note that although we spend 90% of our time within buildings (EPA, 2015a), building research accounts for 0.2% of all federally funded research (USGBC, 2007).

In the built environment, history has provided us many examples of how changes to one of the sustainability pillars resulted in unintended consequences, both within the pillar and extending to the other pillars. As an example of unintended consequences occurring primarily within the planet pillar, methyl *tert*-butyl ether (MTBE) provides an interesting illustration. In removing lead from gasoline, MTBE was recommended by the US Environmental Protection Agency's (EPA) reformulated gasoline program as one of several fuel additives that could boost octane content and oxygenate gasoline (Erdal and Goldstein, 2000), with the intended benefit of reducing air pollution. Unfortunately, MTBE's high water solubility (~43,000 part per million (ppm)) (Sutherland et al., 2004) had the unintended consequence of vastly increasing the extent of soil/water contamination from leaking underground storage tanks, a concern previously expressed by EPA's environmental scientists (EPA, 1992; Erdal and Goldstein, 2000). A review of 700 service station sites in the United States revealed that >80% of the active sites and 74% of the inactive sites had MTBE contamination (Hatzinger et al., 2001).

History has also provided us with many examples of how changes in one of the pillars resulted in unintended consequences in another pillar. An excellent example is "sick building syndrome" (SBS). In short, the energy crisis of the 1970's significantly increased the cost of heating or cooling a building (profit). Building owners, faced with these increasing costs, tried to decrease their energy costs by increasing the building efficiency through insulation and decreasing the amount of fresh or makeup air to the building (profit). The unintended consequence was an increase in indoor air pollution that concurrently increased health complaints from the building occupants resulting in "sick building syndrome" (people). At the height of the crisis, the World Health Organization (WHO) estimated that up to 30% of the new and remodeled buildings may have been linked to "sick building syndrome" (EPA, 1991). Approximately 30–70 million workers in the U.S. were estimated to have exhibited SBS related symptoms (Mikatavage et al., 1995).

This paper will focus upon two legacy materials issues from a triple bottom line sustainability perspective as well as a current class of building materials centered on nanotechnology. This is quite important given that the number of unique substances available to create new materials and products has expanded at an exponential rate. As an example, the Chemical Abstracts Service (CAS) Registry for unique chemical substances has seen a 730-fold increase from 1965 through 2014 as illustrated in Fig. 2. (e.g., alloys, coordination compounds, minerals, mixtures, polymers and salts, and sequences) (Binetti et al., 2008; CAS, 2008, 2011, 2014a, 2014b). The exponential equation of the trendline in Fig. 2 shows that the CAS substances increased at an annual rate of about 11.6%. This increase in the creation of new substances has coincided with an increase in the number of building materials available for use. Case in point, there are over 100 types of decking materials today (Colgan, 2009; Pepitone, 2009) compared to four wood types in the 1970s (StarCraft, 2014). Given the explosion of building materials in use today, we present an alternative, lower cost method that employs up-front, proactive research to prevent/attenuate future legacy issues. The proposed path is sustainable - pay a little now to understand a building material's potential health and environmental impact rather than paying dearly later when a building material is broadly deployed throughout society having unintended health and/or environmental consequences.

2. Materials and methods

Observing temporal and spatial patterns of legacy materials and its effect upon the three sustainability pillars is a critical part of this paper. In using statistical data and analysis, the sustainability

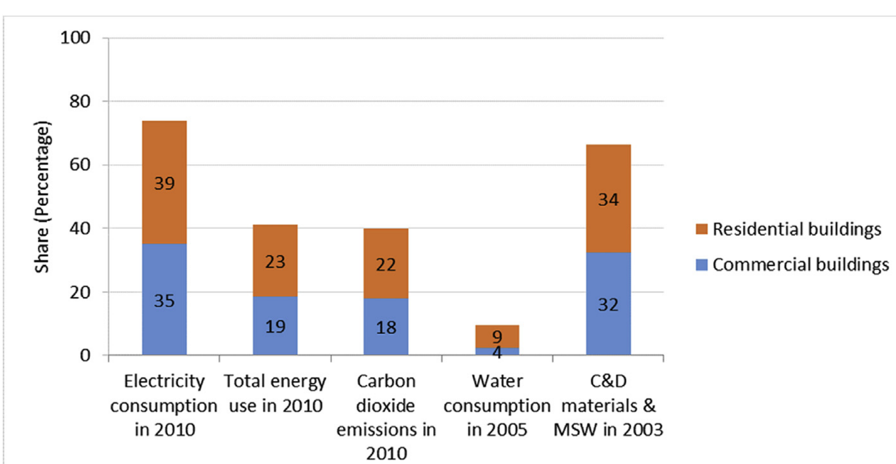

Fig. 1. Buildings and infrastructure's (B&I) impacts. Data from 1. EERE (2012a), "Building energy data book, table 1.1.3 & 1.1.9" for energy use & electricity consumption, "table 2.4.1 & 3.4.1" for CO_2 emission, "table 8.1.1" for water consumption, and "table 1.4.14" for construction & demolition (C&D) materials; 2. EPA (2009) for municipal solid waste (MSW); 3. Kenny et al. (2009) for water consumption.