

1 Calculating the Carbon Cost in Critical Care: A Global View 2 from an Intensive Care Window

3 P Ramesh Menon

4 Received: 11 December 2012 Accepted: 5 January 2013 Published: 15 January 2013

5

6 **Abstract**

7 The "Global Climate Change and Children's Health" is a technical report and policy
8 statement (1), that outlines the specific ways global climate change impacts child health, and
9 calls on health practitioners to understand the threats, anticipate the impact on health, and
10 advocate for strategies that will lessen the effects. A carbon footprint is defined as: The total
11 amount of greenhouse gases produced to directly and indirectly support human activities,
12 usually expressed in equivalent tons of carbon dioxide (CO₂). It is often understood as in the
13 following examples: Other greenhouse gases which might be emitted as a result of human
14 activities are methane and ozone. These greenhouse gases are normally also taken into
15 account for the carbon footprint. They are converted into the amount of CO₂ that would
16 cause the same effects on global warming. This is called equivalent CO₂ amount. Carbon
17 footprint may also be expressed in kg carbon rather than kg carbon dioxide (By multiplying
18 with a factor 0.27 i.e. 1'000 kg CO₂ equals 270 kg carbon).

19

20 **Index terms—**

21 **1 Introduction**

22 The "Global Climate Change and Children's Health" is a technical report and policy statement (1), that outlines
23 the specific ways global climate change impacts child health, and calls on health practitioners to understand the
24 threats, anticipate the impact on health, and advocate for strategies that will lessen the effects.

25 A carbon footprint is defined as: The total amount of greenhouse gases produced to directly and indirectly
26 support human activities, usually expressed in equivalent tons of carbon dioxide (CO₂). It is often understood
27 as in the following examples:

28 Other greenhouse gases which might be emitted as a result of human activities are methane and ozone. These
29 greenhouse gases are normally also taken into account for the carbon footprint. They are converted into the
30 amount of CO₂ that would cause the same effects on global warming. This is called equivalent CO₂ amount.
31 Carbon footprint may also be expressed in kg carbon rather than kg carbon dioxide (By multiplying with a factor
32 0.27 i.e. 1'000 kg CO₂ equals 270 kg carbon).

33 The carbon footprint is a very powerful tool to understand the impact of personal behaviour (including
34 healthcare) on global warming. Individual activities like, e.g. travelling by car, train, bus or air plane, fuel
35 consumptions, electricity bills are called "carbon stamps" (individual contributions). In the medium-and long
36 term, the carbon footprint must be reduced to less than 2'000 kg CO₂ per year and per person. (2)

37 Author: Registrar, PICU Royal Children's Hospital Melbourne Australia. e-mail: rpmpgi@gmail.com
38 Keywords: carbon footprint, ventilation, health.

39 Carbon footprint in the ICU: In the medical parlance, Carbon dioxide (CO₂) is produced by cell metabolism in
40 the mitochondria. It depends on the rate of metabolism and the relative amounts of carbohydrate, fat and protein
41 metabolized. The amount is about 200ml.min⁻¹ when at rest and eating a mixed diet; this utilizes 80% of the
42 oxygen consumed, giving a respiratory quotient of 0.8 (RQ = rate of CO₂ production / rate of O₂ consumption).
43 A carbohydrate diet, in a healthy human in a resting state, gives a quotient of 1 and a fat diet 0.7. (3) In a sick
44 child as the metabolic processes are in a compensatory overdrive / decompensated mode, the CO₂ production

2 CARBON COST AND HEALTH CARE (A GLOBAL VIEW):

45 increases and the homeostatic processes go into overdrive with increasing Work of breathing (WoB) to eliminate
46 the excess CO₂ generated and to get more O₂ available for gas exchange. (4) It is in this context of increased
47 WoB that the intensivist manages the patient with Mechanical ventilation and sedation/analgesia and nutrition
48 (enteral or parenteral) and supportive care (temperature / fluid etc).

49 Considerable changes in healthcare delivery practices have been suggested and adopted to improve efficient
50 utilisation of energy.(5,6) However, no formal assessment of actual health care/delivery services in terms of their
51 carbon footprint/ stamps have been done to date. (7) This would enable improvisations of the services which
52 consume the energy rather than the technology available to the end user.(2) While the Hospital sector and health
53 care organizations have made great efforts to improve hospital sustainability practices, the transition may be
54 guided by Life Cycle Assessment (LCA),(8) a method being increasingly used to determine the entire "cradle to
55 grave" economic and climatic effects (carbon cost) of processes and products. (9) Advanced computing methods
56 have been used to look at the amount of CO₂ produced for energy consumed per unit of medical equipment
57 (e.g.: cannulae, ventilator, operation theatre equipment, anesthetic gases etc) and other healthcare accessories
58 including hospital buildings, biological waste disposal etc. (5, ??, ??0,11). However, computing carbon cost of
59 actual processes of health care interventions (like cannulation, mechanical ventilation, parenteral nutrition) have
60 not been considered, yet. It is only recently that an T Each of the following activities adds 1 kg of CO₂ to carbon
61 footprint:-? Travel by public transportation (train or bus) a distance of 10 to 12 km

62 ? Drive by car a distance of 6 km (assuming 7.3 litres petrol per 100 km)

63 ? Fly with a plane a distance of 2.2 km ? Operate a computer for 32 hours (60 Watt consumption assumed)

64 ? Production of 5 plastic bags/ 2 plastic bottles/ one third of an American cheeseburger (the production of each
65 cheeseburger emits 3.1 kg of CO₂!) approach at estimating the carbon cost of "processes" in service of the end
66 user have begun to be looked at.(6) Sustainable health care practices can be maintained into future by conserving
67 an ecological balance. Its relative importance may be assessed by audits that found over 8% of US total carbon
68 cost originating from health care system. (12) Here, we intend to look at the concept of carbon cost of the process
69 of mechanical ventilation of a sick child, in the intensive care setting, to understand the perspective of accounting
70 for the individual practices of health care intervention in terms of their ecological impact. Hypothesis: In a
71 ventilated child, other supportive care remaining the same (e.g. sedation / analgesia / nutrition / temperature/
72 inotropic support), the PaCO₂ levels across time (x axis: time; y axis: PCO₂) would directly yield the carbon
73 footprint of the process of mechanical ventilation (in their respective modes of ventilation) for the duration of
74 ventilation.

75 Approximately 75% of carbon dioxide is transported in the red blood cell and 25% in the plasma. There
76 is a difference between the percentage of the total carbon dioxide carried in different forms in blood and the
77 percentage exhaled from them. For example, 5% of the total is in solution (in plasma) but 10% of exhaled carbon
78 dioxide comes from this source; 10% is protein bound, particularly with Hb, but this supplies 30% of the exhaled
79 amount. This corresponds to 0.5ml.kPa⁻¹ carbon dioxide in 100 ml blood at 37°C. The partial pressure of carbon
80 dioxide is 5.3pKa in arterial blood and 6.1kPa in mixed venous blood; therefore, arterial blood will contain about
81 2.5ml per 100ml of dissolved carbon dioxide and venous blood 3ml per 100ml. A cardiac output of 5l.min⁻¹ will
82 carry 150ml of dissolved carbon dioxide to the lung, of which 25ml will be exhaled. Because of this high solubility
83 and diffusion capacity, the partial pressure of carbon dioxide in alveolar and pulmonary end-capillary blood are
84 virtually the same.(3) Hence PA CO₂ (= PaCO₂) is a direct correlate of CO₂ produced in metabolically active
85 tissues of the body and brought to the lungs for exhalation, via blood. PaCO₂ is the only blood gas measurement
86 that provides information on VA. Furthermore, PaCO₂ states directly, with one number, the relationship of VA
87 to carbon dioxide production, at least at the time the sample is taken. (4) The production of CO₂ (and thereby
88 PaCO₂) in a steady state is dependent on the metabolic state of the tissues and the work done by the mechanical
89 ventilator (which offloads the work of breathing in a sick child). After the initial stabilization of a sick child,
90 the metabolic state of the tissues attains a new equilibrium, including the work shouldered by the mechanical
91 ventilator. (4) Other factors and interventions like sedatives/ analgesics / inotropes/ parenteral nutrition etc are
92 significant factors in the attainment of the equilibrium. Once attained, the metabolic equilibrium is a function
93 of the underlying disease process and the compensatory work demand performed by the mechanical ventilator.
94 Given that the body's homeostatic mechanisms in overdrive / distress become less efficient (generating more
95 CO₂ in disease / decompensated state), mechanical ventilation may actually have benefits in terms of saving the
96 carbon cost due to the disease or death. There has to be a method of quantifying the carbon cost of the process
97 of health care intervention.

98 This concept of saving carbon cost with health care intervention (like heart surgery) (13, 14) finds an echo in
99 the similar concept of carbon cost saved in the process of E-news. (15) Technical improvements in any specific
100 sector (e.g. communication, transportation) may not generate per capita reductions in energy use or GHG
101 emissions as large as reductions possible through changing the means by which people achieve the ends currently
102 provided in those sectors (e.g. E-news, social interaction). However, reductions are constrained by how well the
103 alternative (e.g., e-readers, vehicle sharing) substitutes for the existing means of providing the service. (??5)

104 2 Carbon cost and health care (a Global view):

105 This reminds people in health care that we're not a trivial part of the issue. The primary focus is on issues
106 surrounding patient safety, health care quality, and cost containment at this current point in time. The health

107 care sector, in general, may be a bit slower than other sectors to put this [emissions] on their radar screen.
108 But given the focus on health care policy and environmental policy, it might be interesting if not wise to start
109 accounting for environmental externalities in health care.

110 According to a WHO report (16)

111 ? Climate change affects the fundamentals for health -clean air, safe drinking water, sufficient food and
112 secure shelter. ? Many of the major killers such as diarrhoeal diseases, malnutrition, malaria and dengue are
113 highly climate-sensitive and worsen as the climate changes. ? Areas with weak health infrastructure -mostly in
114 developing countries (12). -will be the least able to cope without assistance to prepare and respond.

115 Treating climate-related ills will require preparation, and early-warning systems. Climate change can
116 contribute to such diseases as diarrhea, malaria and infectious illnesses in a number of ways. (17,18) In warmer
117 temperatures, for example, the parasite that spreads malaria via mosquitoes develops more quickly. (??7) A 2000
118 study conducted in Peru (19) found that when the periodic El Nino phenomenon boosted temperatures there,
119 hospital admissions of children with diarrhea increased exponentially.

120 Pediatric perspective: For children, this can mean post-traumatic stress, loss of caregivers, disrupted education
121 and displacement. Increased climate-sensitive infectious diseases, air pollutionrelated illness, and heat-related
122 illness and fatalities also are expected. (20) Disruptions in the availability of food and water and the displacement
123 of coastal populations can cause malnutrition, vitamin deficiencies and waterborne illness. Direct health impacts
124 from global warming include injury and death from more frequent extreme weather events, such as hurricanes
125 and tornados. India, like most other developing countries with high growth indices can grow differently, because
126 "it is in an early stage of development". In other words, it can leapfrog to a low carbon economy, using high-end
127 and emerging technologies and by being different. As doctors, our field of care must broaden to ensure that
128 today's children who would inherit the burden of our actions today and bequeath it to tomorrow's children, are
129 well prepared. The new paradigm of an abruptly changing climate system has been well established by research
130 over the last decade, but this new thinking is little known and scarcely appreciated by the wider community of
131 natural and social scientists and policy makers-National Academy of Sciences/National Research Council 2002.
132 (??)II.

133 Hospital Perspective 1) Use point of contact for health care delivery to discuss with parents regarding potential
134 impact on health of climate change. Antenatal clinics, Immunisation clinics, well baby clinics; School health
135 services .Doctors can effectively create awareness about "future" effects of climate change; make sure that patients
136 understand the air quality index, pollen counts and UV measures used in most metropolitan areas. These may
137 be opportunities to introduce the broader issue of climate change and the importance of reducing CO2 emissions.

138 5) Emulate other hospital sectors and organisations that have made great efforts to improve hospital
139 sustainability practices e.g.: using less volatile anesthetics like desflurane. (??) Some measures that hospitals
140 can use to improve energy efficiency include creating recycling programs and purchasing goods and services from
141 environmentally friendly suppliers. At the University of Chicago Medical Centre, the Sustainability program has
142 implemented a plastic recycling program that diverts more than 500 pounds of waste each day from landfills to
143 recycling plants and ensured that 90 percent of cleaning supplies used by the hospital have Green Seal certification.
144 Such efforts have reduced waste costs from \$55,000 per month to \$35,000 per month, suggesting that reducing
145 environmental impact can go hand in hand with reducing costs in a hospital setting. An audit of Hospital
146 care, scientific research and the production and distribution of pharmaceutical drugs, found that they produce
147 3-8% of the total carbon dioxide output. (5, ??) The audit used 2007 health care spending and a model of
148 environmental impact, called the environmental input-output life cycle assessment (EIOLCA) model, developed
149 by the Green Design Institute at Carnegie-Mellon University. The analysis found that hospitals were by far
150 the largest contributor of carbon emissions in the health care sector, and were attributable to the high energy
151 demands needed for temperature control, ventilation and lighting in large hospital buildings. The second largest
152 health care contributor to the overall carbon footprint was the pharmaceutical industry, where carbon emissions
153 were attributable to manufacturing combined with transportation costs associated with distribution.

154 **3 5) Policy advocacy:**

155 To advocate and support policies that strengthens public transportation, expand green spaces and reward energy
156 efficiency. It's also crucial that children are given specific attention in emergency and disaster response planning.

157 According to the Intergovernmental Panel on Climate Change (21,22) global mean temperatures could increase
158 by 1.5 to 5.8 °C by the end of the next century in response to this additional radiative forcing. While this may
159 appear to be a minor warming when compared to diurnal or seasonal amplitudes of the temperature cycle, it
160 should be emphasised that this is a warming unprecedented in the last 10000 years. It is time for a motivated
161 implementation of on-the ground adaptation strategies and policy initiatives immediately. ¹ ²

¹© 2013 Global Journals Inc. (US) © 2013 Global Journals Inc. (US)

²()

3 5) POLICY ADVOCACY:

162 [Epstein et al. ()] 'Biological and physical signs of climate change: focus on mosquito-borne diseases'. P R Epstein
163 , H F Diaz , S Elias . *Bull Am Meteorol Soc* 1998. 78 p. .

164 [Menon] *Carbon Cost of Health Care: New Thoughts*, P R Menon . <http://healthsciences.ac.in/julysep12/Contents.html>

165 [Houghton et al. ()] *Climate change 2001: the scientific basis: contribution of the Working Group I to the third
166 assessment report of the Intergovernmental Panel on Climate Change*, J T Houghton , Y Ding , D J Griggs .
167 2001. Cambridge, England: Cambridge University Press.

168 [Paul ()] 'Climate Change and Human Health'. R E Paul . *N Engl J Med* 2005. 353 p. .

169 [Beniston ()] 'Climate change: possible impacts on human health'. Martin Beniston . *Swiss Med Wkly* 2002. 132
170 p. .

171 [Checkley et al. ()] 'Effect of El Niño and ambient temperature on hospital admissions for diarrhoeal diseases in
172 Peruvian children'. W Checkley , L D Epstein , R H Gilman , D Figueroa , R I Cama , J A Patz , R E Black
173 . *Lancet* 2000. 355 p. .

174 [Crane et al. ()] *Energy Services Analysis: An Alternative Approach for Identifying Opportunities to Reduce
175 Emissions of Greenhouse Gases*, Keith Crane , Liisa Ecola , Scott Hassell , Shanthi Nataraj . 2012. Santa
176 Monica, CA: RAND Corporation.

177 [Chung and Meltzer (2009)] 'Estimate of the carbon footprint of the US health care sector'. J W Chung , D O
178 Meltzer . *JAMA* 2009 Nov 11. 302 p. .

179 [Shea ()] 'Global climate change and children's health'. K M Shea . *Pediatrics* 2007. 120 p. .

180 [Berners-Lee ()] *How bad are bananas?: the carbon footprint of everything*, M Berners-Lee . 2011. Vancouver,
181 Greystone Books.

182 [Mills ()] 'Insurance in a climate of change'. E Mills . *Science* 2005. 309 p. .

183 [Ipcc. Climate and Change ()] Ipcc. Climate , Change . *Volumes. I (Science) II (Impacts) and III (Socio-
184 economic implications*, (New York) 1996. Cambridge University Press. (The IPCC Second Assessment Report
185 Cambridge and)

186 [Life cycle assessment: From the beginning to the current state Klöpffer W. *Environ Sci Pollut Res Int* ()] 'Life
187 cycle assessment: From the beginning to the current state'. Klöpffer W. *Environ Sci Pollut Res Int* 1997. 4
188 (4) p. .

189 [Leaf ()] 'Potential health effects of global climatic and environmental changes'. A Leaf . *N Engl J Med* 1989.
190 321 p. .

191 [Mcgain et al. (2012)] 'Workplace sustainability: the "cradle to grave" view of what we do'. F Mcgain , D Story
192 , E Kayak , Y Kashima , S Mcalister . *Anesth Analg* 2012 May. 114 p. .

193