investigate this more rigorously with prospective studies and we would invite other interested parties to contact us.

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No competing interests declared.

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Converting gas-driven ventilators from oxygen to air: environmental implications

We read the recent correspondence by Ford and Foale with great interest [1]. In preparation for 'surges' of the COVID-19 pandemic, converting 'bag-in-bottle' ventilators to use air as the driving gas reduces oxygen use, thereby preserving supplies for the treatment of patients at times of unprecedented clinical need. We would like to highlight that this innovation may also have important benefits from an environmental perspective.

Oxygen is produced by the fractional distillation of liquified air, a more energy-intensive process than the compression of air for medical purposes. Based on data from Ecoinvent [2], the production of 1 l of oxygen requires approximately 0.001 kWh of electricity, whereas the production of 1 l of medical air requires 0.0003 kWh.

According to Ford and Foale, using air as the driving gas would save 449,280 $l.day^{-1}$ of oxygen in their 52 anaesthetic machine-department [1]. However, their calculations assume providing ventilation 24 $h.day^{-1}$ using all their anaesthetic machines.

Based on Ford and Foale's work, we calculated the energy savings of converting the driving gas to air in routine circumstances (6 $h.day^{-1}$, 5 $days.week^{-1}$, 48 $weeks.year^{-1}$); this would generate an annual energy saving of 363 kWh per ventilator. We then calculated the corresponding CO_2 equivalent (CO_2e) savings, based on the carbon intensity of electricity generation [3]. Modelling this in different countries yields widely varying results (Table 1).

Table 1 Carbon intensity of electricity production in four different countries [3], and the corresponding carbon footprint savings of using air instead of oxygen as the ventilator driving gas; carbon footprint saving data are per ventilator, per year.

	Carbon intensity of electricity production (kg $CO_2e.kWh^{-1}$)	Carbon footprint saving (kg CO_2)
Norway	0.01	3.63
UK	0.28	101.61
USA	0.48	174.18
China	0.62	224.99
Australia	0.90	311.94

Our calculations demonstrate the importance of the method of electricity generation in the country where medical gases are produced. In Norway, where electricity is generated largely from renewable sources, there is little to be gained; whereas in Australia, where power stations are predominantly coal-fired, an annual saving of over 300 kg CO_2e can be made per ventilator. In Ford and Foale's 52 anaesthetic machine-department in the UK, a 5.28 tonne annual CO_2e saving could be made; equivalent to driving over 25,000 miles in an average car emitting 130 g $CO_2.km^{-1}$.

Financial implications vary internationally, but medical gases are generally inexpensive when pipeline-supplied, and the cost differential is therefore minimal. In the UK, for example, 10^5 l of oxygen at 15°C costs approximately £2.85 when pipeline-supplied, though it can cost as much as 0.5 $p.l^{-1}$ when supplied in cylinders (personal communication, BOC Healthcare). Air is compressed on-site at most hospitals; based on a price of 15 p per kWh of electricity, 10^5 l of medical air would cost approximately

£4.50. This represents a small annual cost increase of £8.55 per ventilator, based on our above example.

There are some caveats to our calculations: we assume that positive pressure ventilation is used for 6 h per working day; unsupported spontaneous ventilation does not require driving gas so would further reduce the carbon footprint. Also, we do not account for gas transport or storage, which varies according to the location of the institution and the storage systems used. Ford and Foale point out that oxygen "*was traditionally thought to be a more reliable [driving] gas*" [1], and if using air results in premature mechanical wear this may offset any carbon saving. Finally, this carbon saving should be interpreted in the context of other changes that anaesthetists can make. For example, though switching an anaesthetic machine from oxygen to air can save 311.94 kg CO_2e per year (in Australia), switching the same machine from desflurane to sevoflurane (assuming 1.0 MAC at age 40, 0.4 l fresh gas flow, 6 $h.day^{-1}$, 5 $days.week^{-1}$, 48 $weeks.year^{-1}$) would yield a saving of 39.24 tonnes CO_2e [4].

Anaesthetists have a responsibility not only to their patients, but for the public health of this and subsequent generations [5]. Though motivated by a worsening pandemic, Ford and Foale have, perhaps unintentionally, reduced the environmental impact of their practice and we congratulate them for this. The effects of COVID-19 will have far-reaching repercussions for anaesthesia; some of which, we hope, will bring benefits for both patients and the planet.

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