A guide for program development of environmentally sustainable kidney care

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Purpose of review
As the health impacts of climate change intensify, health systems globally are transitioning to net zero greenhouse gas emissions and climate resiliency. Kidney care has high environmental impact, and both a coordinated sectoral approach as well as provider-level quality care improvements are needed. Updated, evidence-based strategies for operationalizing environmentally sustainable kidney care are provided.

Recent findings
As Earth warms, rising temperatures are adversely impacting kidney health, and both the prevalence and severity of kidney diseases are projected to worsen. Kidney care providers seek ways to implement planetary healthcare, and a framework of improved education, ongoing research activities, enhanced sustainability performance metrics reporting and accountability is described. Optimized disease prevention through nonpharmacologic as well as pharmacologic strategies, ensuring appropriateness of care [some examples include stewardship of laboratory testing and dialysis prescriptions, increased transplantation (preferably live donor) for those living with kidney failure], and lower impact care through technological improvements and better waste management are described.

Summary
Environmentally sustainable kidney care is high-quality care that is implementation-ready in diverse settings.

Keywords
climate change, environmentally sustainable kidney care, green nephrology, planetary health

INTRODUCTION

The climate crisis is a significant risk to kidney health, and as practitioners devoted to the betterment of the lives of people with kidney disease, our duty of care has expanded to mitigating, and adapting kidney health delivery systems to, the effects of climate change [1]. Though the primary focus of this article is mitigating the environmental effects of kidney care, it is stressed that kidney programs must understand regional kidney health risks and vulnerabilities associated with climate change, and ensure that emergency management plans are well developed and rehearsed [2,3]. A strategy that addresses both mitigation of, and adaptation to, climate change through enhanced understanding of climate science has recently been adapted to kidney care [4]. Our rapidly evolving understanding of the detrimental effects of heat on kidney health underscore kidney care providers' need to transition to low carbon, sustainable, and climate resilient care through both a coordinated sectoral approach as well as widespread implementation-ready program level practice changes.

HEAT EFFECTS ON KIDNEY HEALTH

Described as 'an extraordinary streak of record-breaking temperatures', the years 2015–2024 are the 10 warmest years on record [5]. Already known to impact admissions for nephrolithiasis, the effects of ambient temperatures on both acute [6] and chronic [7▪▪] kidney diseases (CKD) are now better understood. In a recent report from the UK, widely known for its historically temperate climate, the odds of acute kidney injury (AKI) were 1.6 times more likely on a day with 32 °C versus 17 °C. Further,

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KEY POINTS

- Earth's rising temperatures are increasingly detrimentally affecting kidney health, and kidney health delivery has significant environmental impact.
- Kidney care providers must understand regional health risks and vulnerabilities associated with climate change, and ensure that emergency management plans are well developed and rehearsed.
- The environmental impacts of kidney care increase as kidney health declines, with care-related greenhouse gas emissions intensifying progressively from predialysis CKD care to transplantation, to dialysis care.
- Environmentally sustainable kidney care can be achieved through both sectoral and provider-level efforts toward education, ongoing research, key performance indicator iterative measurement and reporting, and stakeholder accountability, aiming to achieve the highest attainable equity and wellbeing.
- The environmental impacts of kidney care can be reduced through implementation-ready effective chronic disease prevention and management, stewarding healthcare resources, sustainable procurement, and emerging technological advances in the provision of dialysis care.

the odds of AKI were an impressive 1.02 per 1 °C increase above 17 °C. In a secondary analysis of the DAPA-CKD trial, and independent of diabetes status, sex, age, albuminuria, use of select pharmacotherapies including diuretics, and income setting, individuals with estimated glomerular filtration rate (eGFR) under 45 ml/1.73 m^2 were estimated to experience an additional eGFR decline of 3.7 ml per 1.73 m^2 per year when located in a very hot versus a temperate environment.

PLANETARY HEALTH, ENVIRONMENTAL SUSTAINABILITY, AND KIDNEY CARE

The Planetary Health Roadmap advises the identification of coordinating entities, prioritization of education, research, funding, measurement, and reporting; industry involvement, and communications and accountability as key to achieving the highest attainable equity and wellbeing [8].

According to a recent global survey of kidney care providers, with respondents from over 100 countries (68% of whom were from lower income or middle-income countries), only 22% of respondents' programs are involved in any environmentally sustainable kidney care (ESKC) initiative, with engagement independent of income level [9▪]. Insightful prioritizations that reflect the PHA Roadmap guidance were gleaned, including the need for toolkits, continuing education, and improved opportunities for ESKC in practice settings as preferred implementation aids, and preventive care and more system-level sustainability opportunities as implementation priorities.

Bajpai *et al.*[10▪] identified patient, provider, and system-level barriers to ESKC (Fig. 1), and proposed a series of practice and policy implementation initiatives ranging from improved kidney disease prevention to promoting transplantation uptake to better waste management. Though the focus was on lower income and middle-income settings, the systems approach and themes identified are of general applicability. In the European setting, KitNewCare investigators are collaboratively developing a benchmarking tool to aid ESKC implementation, with consensus-derived and rigorously derived metrics in health, social and environmental impact, and cost realms included (Table 1) [11].

Both KitNewCare [12▪] and the International Society of Nephrology's (ISN) Global Environmental Evolution in Nephrology and Kidney Care (GREEN-K) initiative [13▪] have identified technical innovations in kidney care products and services as necessary to achieve ethical, quality, low environmental impact kidney care, the latter emphasizing financially accessible procurement (of the entire range of products and services provided, from pharmaceuticals to dialysis equipment and consumables, including their supply chains) as a key lever in this transition [14▪]. The ISN is currently developing a toolkit with step-by-step direction for programs to create their own ESKC program [15▪].

Practicing sustainably extends beyond pharmacotherapy and dialysis provision, both discussed below. Low protein (particularly animal sourced) and/or plant-based diets low in ultra processed content are of renewed interest for planetary stewardship in addition to health benefit [16], and Renouf and Wong [17] have provided helpful guidance how a planetary health menu can be actualized in both kidney nutrition and cultural contexts. Choosing Wisely, an initiative that seeks to optimize appropriateness of care, has identified laboratory testing as an overuse priority [18▪]. Though early CKD diagnosis is necessary for health, Tonelli *et al.*[19] recently informed that nearly 6 million lab tests could be averted over 10 years in one province in Canada, with small numbers of people having a delayed CKD diagnosis by a mean of 1.5 years, if CKD screening in individuals with diabetes and hypertension was changed from annually to every 3 years. Routine surveillance blood test frequency in a cohort of facility hemodialysis patients was reduced from

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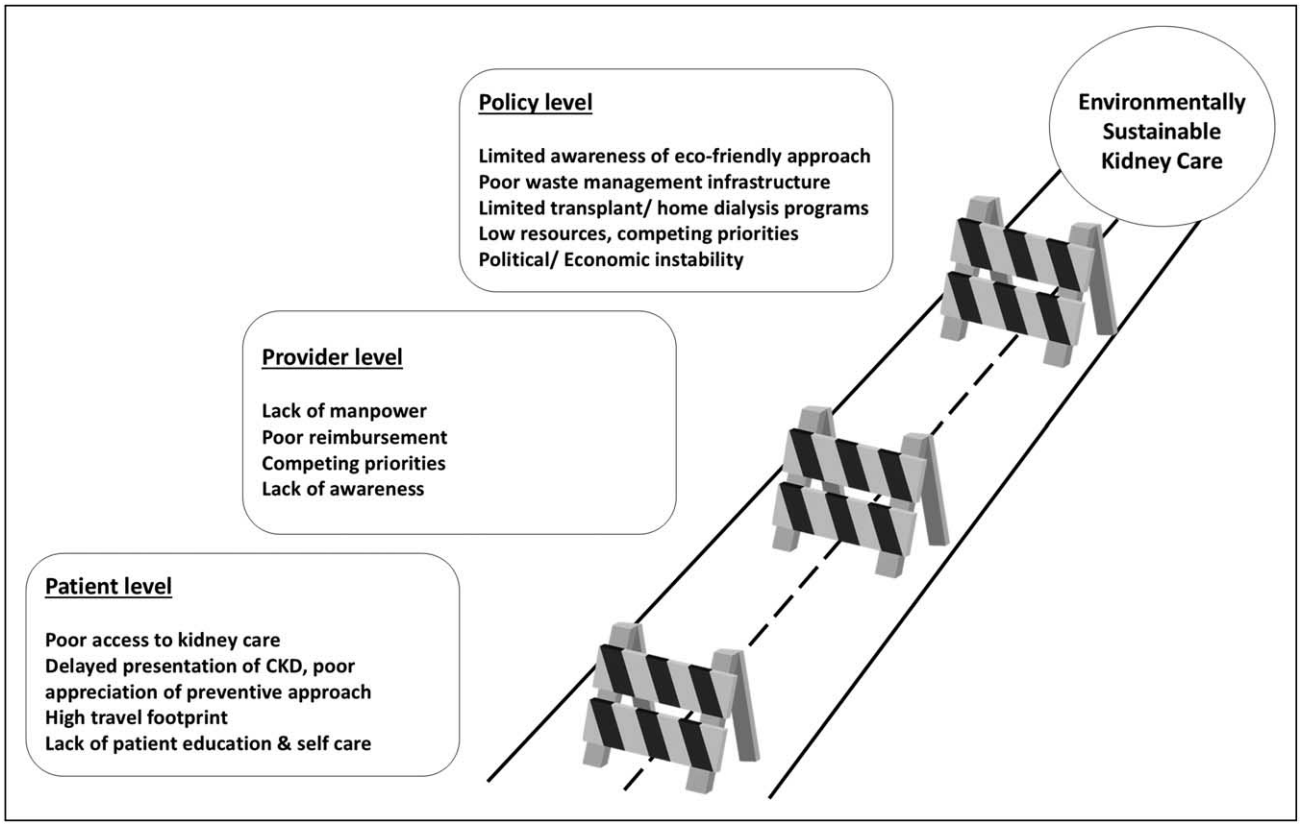


FIGURE 1. Barriers to environmentally sustainable kidney care at different level. Adapted from [10▪].

every 6 weeks to every 8 weeks in the same health region, with a 0.7% increase in potassium values above 6 mmol/l but no increase in hospitalization or mortality [20]. More data is needed to guide optimal screening and CKD laboratory surveillance strategies to both safeguard health and steward resources.

Practicing sustainably also extends well beyond the bedside, and begins with improved understanding of the environmental impact of healthcare. Nordberg and Petersen, respectively, have called for the inclusion of carbon footprint, and more comprehensive environmental data as end points in randomized controlled trials [[21▪,22]. Resources are now available to aid kidney practitioners in life cycle assessment (LCA) methodology and interpretation [23]. Academic activities have climate impact, with air travel to the 2023 European Renal Association meeting

Table 1. Consensus-derived sustainability key outcome measures per KitNewCare Consortium

Health outcomes	Social impact	Environmental impacts	Costs
Survival rates	Patient experience via the Kidney PREMs survey	Climate change	Overall costs for centre level and pathway level
Prevalence rates	Staff experience – survey to be confirmed	Human toxicity	Resource costs
Transplantation rates	Carer experience- survey to be confirmed	Resource use (fossils, metals, and minerals)	Patient and staff travel
Emergency admissions/ hospitalization rates		Water use	Loss of labour productivity
Infection rates			Return on investment
QoL via the KDQOL SF 12 survey			

Adapted from https://kitnewcare.eu/wp-content/uploads/2025/03/WP5-Milestone-March-2025-Consensus-Report.pdf; accessed online 7 September 2025 [11].

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emitting an estimated 5808 tonnes of carbon dioxide equivalents (CO_2e) [24▪]. Meeting frequency, location, and the environmental offerings of conference venues should be considered by conference planners. The simple but understated 'obligation' of talking to our patients about climate change has been proposed, striving to position patients as partners in the pursuit of sustainable kidney care [25].

OUR EXPANDING KNOWLEDGE OF ENVIRONMENTAL IMPACT THROUGHOUT THE SPECTRUM OF PREDIALYSIS CHRONIC KIDNEY DISEASE CARE

Nagai *et al.*[26▪] used Japanese healthcare expenditure data to calculate the carbon emissions of kidney care. Average yearly per person greenhouse gas emissions for nondialysis CKD versus dialysis cohorts were 0.31 and 3.9 tCO2e, respectively. Not surprisingly, emissions increased with greater CKD predialysis medical complexity, with lowest and highest emissions, respectively, of 0.28 tonnes CO2e for female individuals with CKD stage G2 or higher, and 1.44 tonnes CO2e for male individuals with stages G3a or lower and 30% or more eGFR decline per year (no explanation was provided for the difference between males and females).

Though literature focus remains on greenhouse gas emissions, more comprehensive environmental data are available via an LCA of a modelled CKD pathway in 10 almost exclusively high-income settings [27▪▪]. Garcia Sanchez *et al.* determined the environmental impacts of primary, specialty, and hospital-based (emergency, ward, and intensive) care, as well as those of dialysis and transplant care. Healthcare utilization data was literature and/or expert opinion derived and importantly, included pharmaceutical manufacturing of the five most commonly prescribed medications in a published CKD cohort [28]. As demonstrated in Fig. 2, dialysis and hospitalization are the largest drivers of environmental impact. As such, optimized chronic disease management including preventing CKD progression, increasing transplantation, and reducing travel emissions via virtual care, whenever appropriate, were identified as key strategies to reduce environmental impact.

Preventing CKD progression is recognized as an urgent priority when considering recent 10-year projected increases, across a range of countries, of people with later stages of CKD and those who require dialysis (latter increasing between 3.6 and 170.8% above 2022 baseline) [29▪▪]. The projected increase in associated environmental impacts – including freshwater use, fossil fuel depletion, and greenhouse gas (GHG) emissions – from higher numbers of people receiving a KRT exceeded 11% in all countries.

PREVENTIVE PHARMACOTHERAPY REDUCES CHRONIC KIDNEY DISEASE EMISSIONS

Sodium-glucose co-transporter 2 (SGLT2) inhibitors reduce the risk of hospital admission and kidney failure, and in a recent secondary analysis of the CREDENCE trial were additionally demonstrated to thereby lower GHG emissions [30▪▪]. Emissions from a modeled care pathway's hospital inpatient days, dialysis therapy, and SGLT2 inhibitor tablet production were determined, with mean GHG emissions per participant year of 196 and 157 kg CO_2e in placebo and canagliflozin arms, respectively. To our knowledge, the reduced environmental impact of other pharmacologic and nonpharmacologic preventive CKD strategies remains unknown, but it is intuitive that increasing environmental benefit can be gleaned from increasingly effective, as well as lower emitting care strategies. Emerging preventive combination pharmacotherapies warrant particular attention, noting the 77% increase in global pharmaceutical GHG emissions from 1995 to 2019, highlighting the need for environmental accountability in their entire value chains [31,32].

ENVIRONMENTALLY SUSTAINABLE CARE VIA KIDNEY TRANSPLANTATION

Kidney transplantation is the preferred kidney replacement therapy, with superior survival and cost-effectiveness as compared to dialysis. In addition, early data support transplantation as the most sustainable modality with reduced resource consumption and waste production compared to dialysis [33]. Garcia Sanchez *et al.* inform that the majority of the transplant pathway's carbon footprint originates from organ transport and hospital stay [27▪▪] (Fig. 2). They also noted that emissions were lower for live versus cadaveric donor transplantation (Fig. 3). As such, preemptive and live donor kidney transplantation should be encouraged. Furthermore, they identified several areas in the care pathway, which should be optimized to reduce environmental impact (e.g. the implementation of telemedicine hence reduced travel emissions).

Investigators in the United Kingdom recently assessed the environmental impact of posttransplant care of 68 stable patients following the implementation of virtual clinic follow-up, which involved video appointments with the consultant alternating with reviews via telephone with a transplant nurse over 2 years [34]. Virtual consultations saved 42 666 miles of

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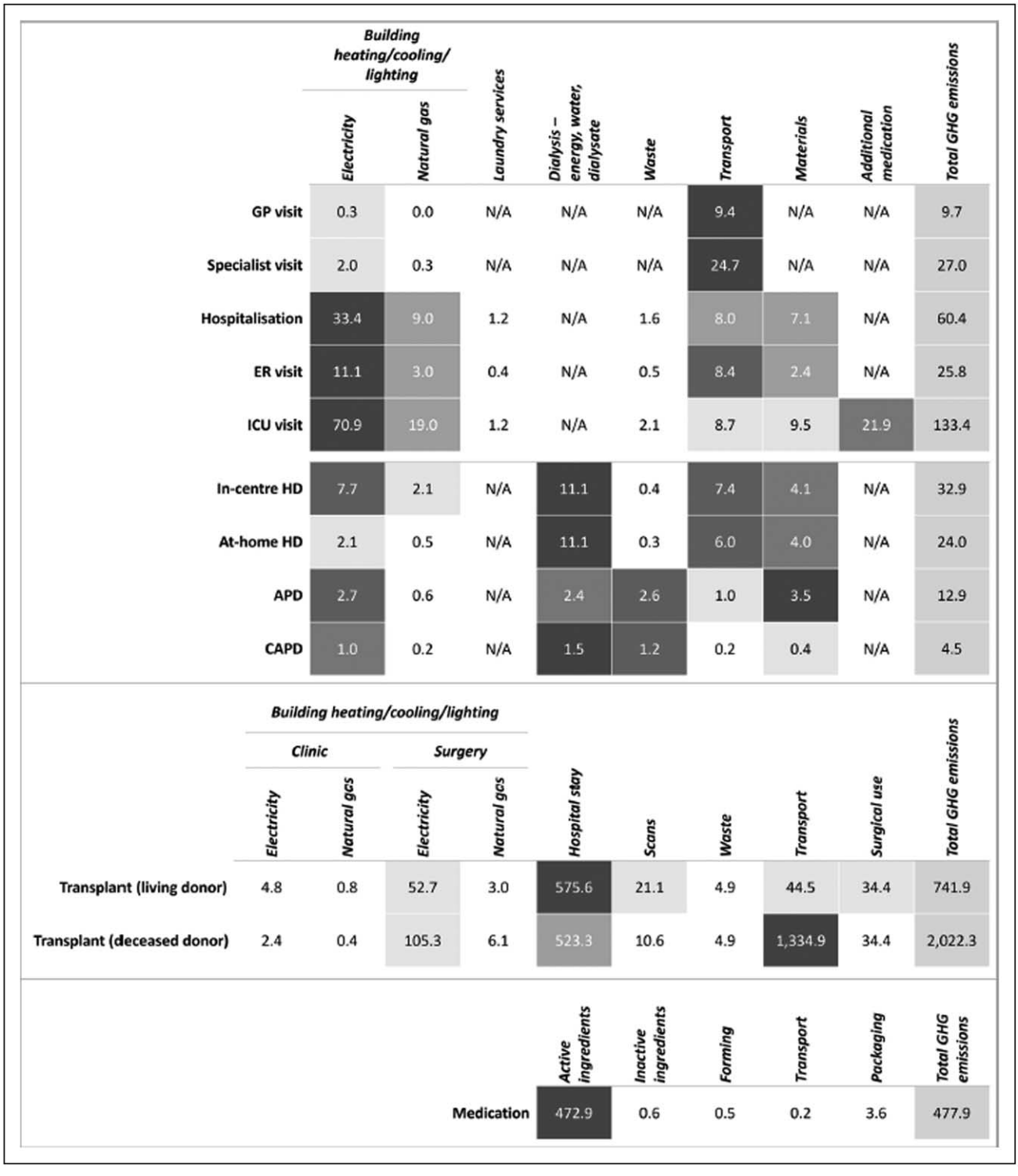


FIGURE 2. Greenhouse gas emissions across all life cycle stages of spectrum of chronic kidney disease care. *Data reported as kg CO_2e. Previously published and taken from [27▪▪]. APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; CKD, chronic kidney disease; ER, emergency room; GP, general practitioner; HD, hemodialysis. Blood tests, supply chain for consumables, capital equipment, staff transportation are excluded.

travel, which resulted in 11 718 kg CO_2e emissions averted. This study, however, did not assess clinical or patient-reported outcomes; further studies are needed to more broadly understand the risks versus benefits of virtual consultations in the posttransplant setting. It is also important to note that the environmental impacts of the pharmaceuticals used in kidney transplantation remain poorly

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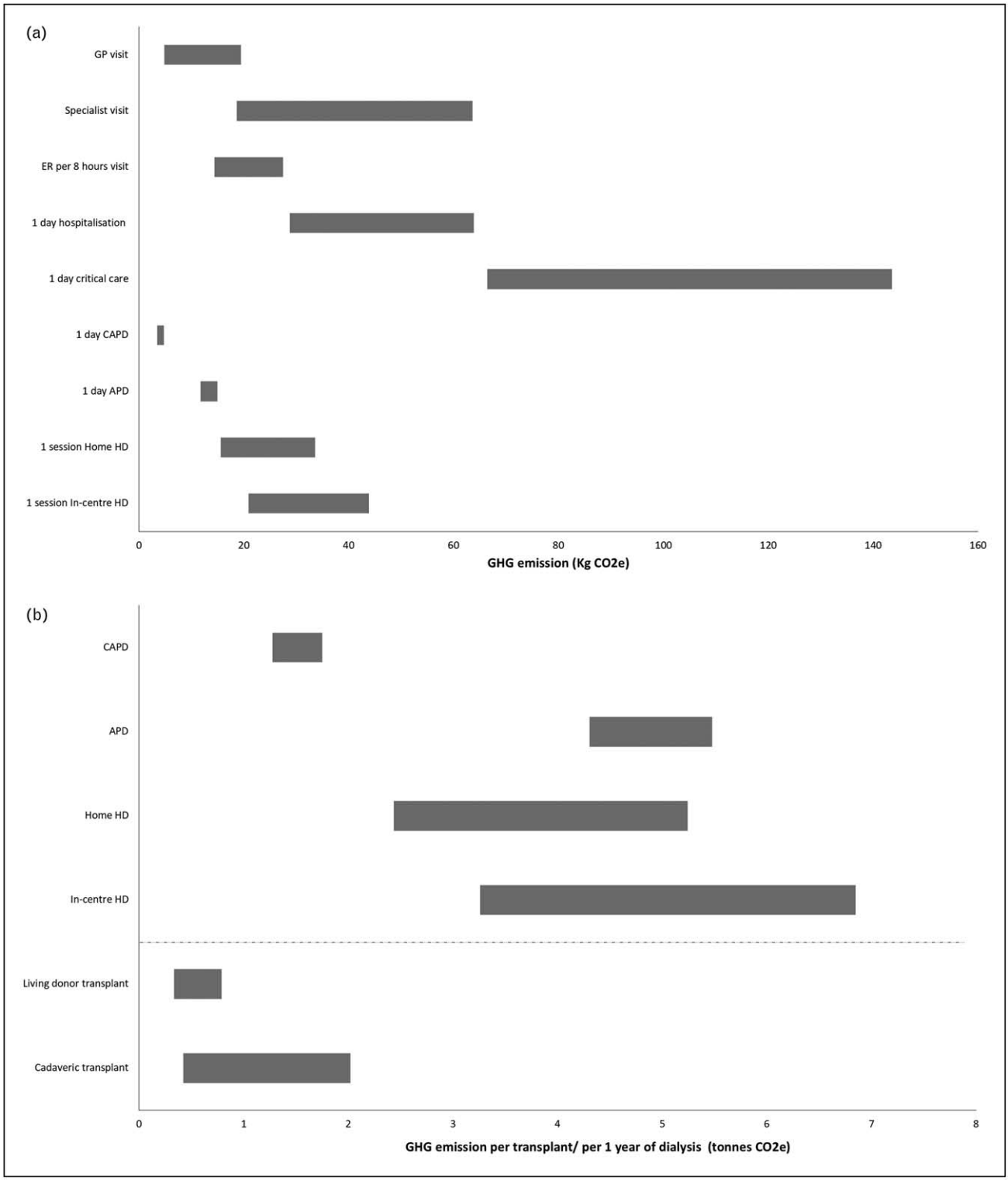


FIGURE 3. Greenhouse gas emissions including ranges across ten health systems, for the CKD care pathway [(a) data expressed in kilograms CO_2e] including kidney replacement therapies [(b) yearly dialysis data expressed in tonnes CO_2e with assumption of 156 HD sessions per annum and PD performed daily; transplant data for one transplant procedure]. Transplant (both live and deceased donor) life cycle boundary includes patient/living donor transportation to the healthcare site, heating/cooling/lighting of this site, all materials involved for the workup scans, stays in hospital (pretransplant and posttransplant), the transplant surgery (both donor and recipient), anaesthetics, and organ transport solution. Adapted from [27▪▪]. APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; CKD, chronic kidney disease; ER, emergency room; GP, general practitioner; HD, haemodialysis; ICU, intensive care unit.

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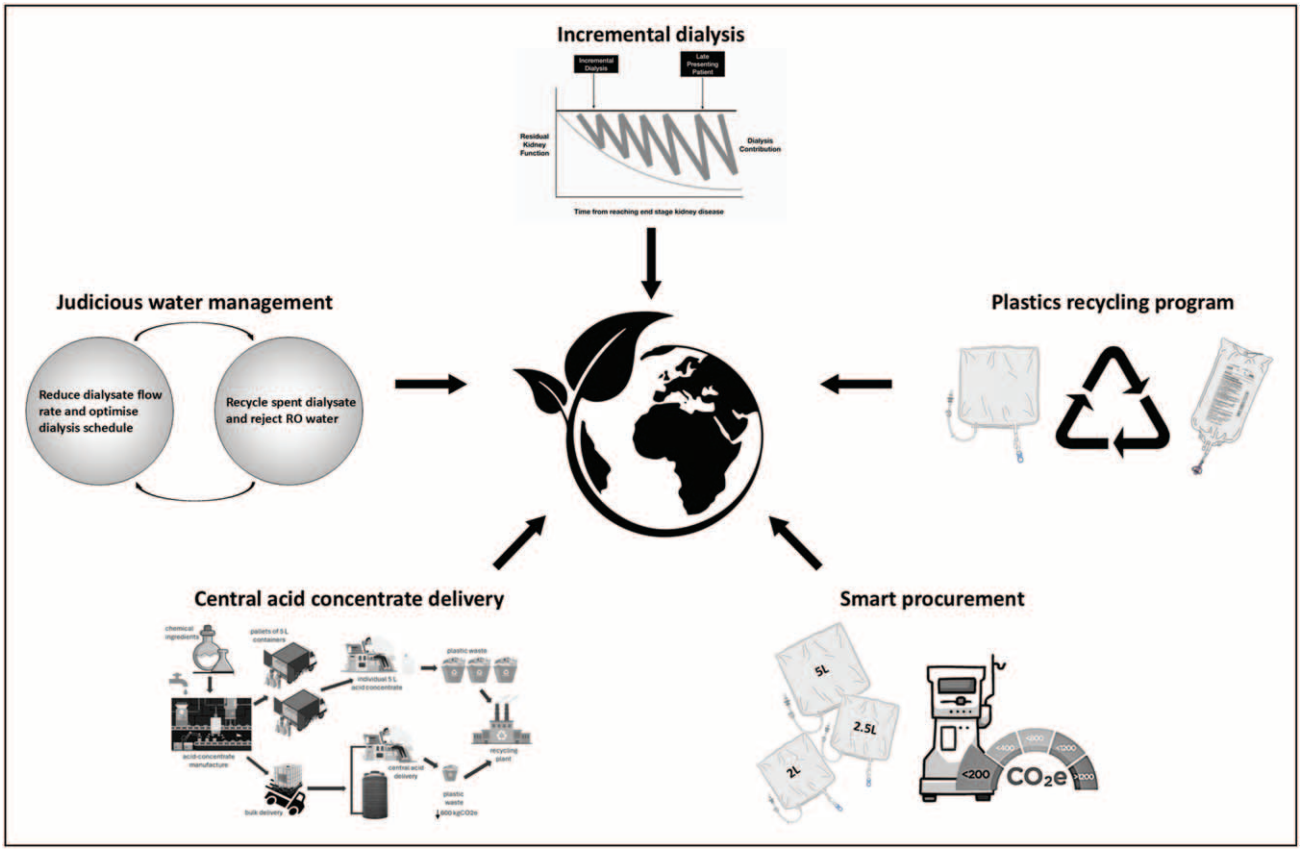


FIGURE 4. Successful examples of environmentally sustainable transformation of dialysis practices.

characterized, although they are likely lower in patients with well functioning versus failing grafts [35].

TRANSFORMING DIALYSIS PRACTICE TO ENVIRONMENTAL SUSTAINABILITY

As dialysis care has the highest environmental impact across the spectrum of kidney care, it is important to promote environmental sustainability into both hemodialysis and peritoneal dialysis (Fig. 4).

ACCESSIBLE OPPORTUNITIES FOR SUSTAINABLE PERITONEAL DIALYSIS CARE

Recent studies reveal peritoneal dialysis prescriptions, consumables waste management, and sustainable procurement as accessible opportunities to improve the environmental performance of peritoneal dialysis therapies. Incremental peritoneal dialysis is the practice in which less than 'standard full-dose' peritoneal dialysis (four exchanges of 2 l bags per day) is prescribed until such time as residual kidney clearance declines and/or symptoms develop [36]. Examples of incremental peritoneal dialysis prescription include having less than four exchanges per day; less than 7 days per week of peritoneal dialysis; and automated peritoneal dialysis with no day dwell or less than 10 l volume dwell per day. McAlister *et al.* recently demonstrated the potential of carbon savings from incremental peritoneal dialysis, where the annual per patient carbon emissions decreased from 1455 to 1072 kg CO_2e using a reduced peritoneal dialysis prescription [37▪▪]. Similarly, another retrospective analysis of 203 incident patients on peritoneal dialysis over 2 years showed that incremental peritoneal dialysis prescriptions saved more than two million litres of water, 9000 kg of plastic and 8000 kg of cardboard as compared to patients who were on full-dose peritoneal dialysis over the same period [38▪].

Furthermore, there is an increased focus on waste reduction via recycling peritoneal dialysis plastics. A peritoneal dialysis centre in Mexico City piloted a polyvinyl chloride (PVC) recycling program involving 12 patients receiving automated peritoneal dialysis for 1 month. One hundred and sixty-seven kilograms of PVC were collected within 1 month

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and recycling avoided the consumption of 131 of water, 20 kW h of energy, and 5 kg of CO_2e emissions for every kilogram of PVC resin recycled, as compared to the production of virgin PVC resin [39▪]. However, upscaling such a program in other healthcare settings is needed to demonstrate feasibility.

Sustainable procurement is another opportunity to steward resources [40]. Ghimire *et al.* recently described that the last bag fill volume used by peritoneal dialysis patients in their centre was less than 1.5 L. The remaining volume of the 2.5 l bag, the only available icodextrin bag in their locality, was wasted [41▪]. They estimated that PVC waste could be reduced by 35% if there was access to 1.5 l bags, highlighting the importance of better alignment of resources for the reduction of healthcare costs and waste.

RECENT ADVANCES IN SUSTAINABLE HEMODIALYSIS PRACTICE

Incremental dialysis is also applied to hemodialysis. A centre in the United Kingdom recently implemented an incremental hemodialysis program for 25 patients and demonstrated an annual emissions reduction of 28.2 tonnes CO_2e with comparable clinical care to standard hemodialysis schedule (thrice weekly 4-h sessions) [42▪▪]. A practical summary for incremental hemodialysis implementation has recently been published [43].

As hemodialysis is water-intensive, judicious water management is paramount to reduce water stress. Two studies recently assessed the water savings potential and clinical safety of reducing dialysate flow from 500 to 300 ml/min. Both studies showed that reduced dialysate flow rate seemed well tolerated without compromising dialysis adequacy, while saving water consumption by 40% [44,45▪]. Similarly, use of dialysate autoflow function and upgrading to a more efficient reverse osmosis system can significantly reduce water usage, saving up to an impressive eight million litres of water annually, as noted in a 40-station hemodialysis unit in the United Kingdom [42▪▪]. Innovative water stewardship has also been successfully implemented in water-scarce regions such as Morocco, leading to more resilient and water-efficient hemodialysis services with capability to repurpose reverse osmosis reject water [[46▪▪,47].

Murcutt *et al.* recently demonstrated that switching from acid concentrate delivery in individual 5 l containers to a central delivery system can result in impressive reductions in CO_2e emissions – approximately 1 tonne per dialysis station per year [48▪▪]. Their program highlighted the importance of considering central bulk delivery during both design and procurement for dialysis facilities for enduring environmental benefit.

It is important to review and upgrade reverse osmosis systems and dialysis machines in any hemodialysis unit, while calling for greater transparency around resource usage provided by the suppliers at procurement [48▪▪]. An Australian group examined two different reverse osmosis systems and types of hemodialysis machines in use in their centres, and noted substantial differences in per-treatment resource consumption [49▪]. Their study highlighted several messages: operators should ensure that the most efficient reverse osmosis settings are applied, and that the functional capacity of the reverse osmosis system optimally matches the number of hemodialysis stations.

CONCLUSION

As our planet warms, acute and chronic kidney diseases are increasing in prevalence and severity. A planetary health approach to kidney health emphasizes reducing disease while providing efficient and high-quality care. Implementation-ready practices and tools are proliferating at sectoral and regional levels, providing strategies to practice sustainably. Inspired by the Planetary Health Roadmap, continued education and research, and expanded measurement, reporting, and accountability – both to people with kidney diseases who we serve, and to our shared environment – are needed, as we continue to work toward the highest attainable equity and wellbeing.

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Conflicts of interest

There are no conflicts of interest.

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An attributional process-based life-cycle analysis was done to quantify the greenhouse gas emissions between full dose peritoneal dialysis versus incremental peritoneal dialysis.

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This is a cost analysis study where the direct healthcare costs and resource utilization associated with incremental and full-dose peritoneal dialysis were quantified.

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A pilot recycling program for the PVC waste from APD was performed in Mexico and this program helps identify barriers to systematic recycling and makes it possible to propose solutions to overcome them, making the program patient friendly and financially sustainable.

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41. ■ Ghimire A, Shah M, Qirjazi E, *et al.* Estimating the costs and amount of recyclable polyvinyl chloride plastic waste associated with discarded Icodextrin. Perit Dial Int 2025:8968608251344074. doi: 10.1177/08968608251344074.

The costs associated with discarded Icodextrin and associated polyvinyl chloride (PVC) plastic waste production were assessed in a renal program In Canada. They noted that better alignment of the availability of icodextrin bags may reduce healthcare costs and PVC waste.

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This is a retrospective review of a series of comprehensive and impactful green initiatives across various aspects of kidney care delivery in a kidney unit in the United Kingdom from 2007 to 2024.

43. Butt U, Davenport A, Sridharan S, *et al.* A practical approach to implementing incremental haemodialysis. J Nephrol 2024; 37:1791–1799.

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A pilot study was conducted in an Indian hemodialysis center to assess whether a novel hemodialysis prescription with high temperature and low flow dialysate can reduce water consumption without compromising the adequacy and safety of dialysis. They showed that increasing dialysate temperature while reducing dialysate flow rate (QD) can be used as a water conservation strategy without compromising the adequacy and safety of dialysis in young and hemodynamically stable patients.

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The implementation of several key strategies as highlighted in this case study done in Morocco can address water scarcity and ensure uninterrupted HD procedures during periods of hydric stress.

47. Tarrass F, Benjelloun M, Razkaoui A, *et al.* Sustainable reuse of hemodialysis reject water for potato farming: a large-scale feasibility study in Morocco. J Nephrol 2025; 38:1279–1286.

48. ■■ Murcutt G, Hillson R, Goodlad C, Davenport A. Reducing the carbon footprint for a 30-bed haemodialysis unit by changing the delivery of acid concentrate supplied by individual 5 l containers to a central delivery system. J Nephrol 2024; 37:1949–1955.

This study investigated whether changing the delivery system for acid concentrate would reduce wastage and any associated greenhouse gas emissions in a 30-bed dialysis unit in the United Kingdom.

49. ■ Barraclough KA, Moller S, Blair S, *et al.* Updating the data: the resource consumption of modern-day hemodialysis systems. Kidney Int Rep 2024; 9: 1521–1524.

An Australian group studied the water and energy requirements of hemodialysis equipment in use in two Australian satellite hemodialysis units under standard operating conditions to assess whether there is any marked variability. They showed that the power and water requirements of modern hemodialysis equipment remains high and variable across centers.

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