Journal of Nephrology

Improving the sustainability and quality of kidney health care through life cycle assessments, quality improvement, education and technical innovations: the KitNewCare approach

--Manuscript Draft--

Manuscript Number:	JNEP-D-24-00448R2
Full Title:	Improving the sustainability and quality of kidney health care through life cycle assessments, quality improvement, education and technical innovations: the KitNewCare approach
Article Type:	Position papers and Guidelines
Funding Information:	HORIZON EUROPE Health (101137054) — Associate Professor Brett Duane
Keywords:	green nephrology; sustainability; environmental burden; Kidney replacement therapy; Dialysis
Abstract:	The KitNewCare consortium aims to create and manage a comprehensive EU-wide programme focusing on sustainability in Kidney Care. The burden of chronic kidney disease is significant and increasing. Around 850 million people have the disease worldwide and by 2030 6 million will need kidney replacement therapy, mainly haemodialysis. As the world population gets older, projections for the end of the century worsen. From a sustainability perspective, healthcare systems contribute around 5-11% of total carbon emissions. Kidney care is one of the most resource intensive specialties. In addition to energy, haemodialysis requires transportation of patients and personnel to and from facilities, uses large volumes of water and generates significant plastic waste. Overall, current dialysis is not sustainable in the medium term. Primary prevention, implementing early diagnosis and treatment of CKD and transplantation will decrease the need for dialysis, but this will take time and even such measures will not prevent the need for dialysis in millions of persons. There is a need to improve knowledge around both the environmental and financial cost of kidney care and also the social and health outcomes of each patient pathway. There is a need for workflow optimizations, organisational transformations and technological innovations across Europe, and a need to learn from different clinical sites. KitNewCare will build a European-wide knowledgebase for sustainability in kidney care, develop and introduce a 4-factor life cycle assessment database for comprehensive impact analysis, implement optimized processes and organizational transformations in four European clinical sites. It will pilot innovations from high-tech small- and medium-sized enterprises with focus on Kidney care, and establish a network for continuous monitoring, benchmarking, and implementation of sustainable solutions across healthcare sectors.
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Response to Reviewers:	Please see word document outlining our responses

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1.1 Abstract

The European Union (EU)-funded KitNewCare consortium aims to create and manage a comprehensive EU-wide programme focusing on sustainability in Kidney Care.

Around 850 million people have chronic kidney disease (CKD) worldwide and by 2030 6 million will need kidney replacement therapy, mainly haemodialysis. As the world population gets older, projections for the end of the century worsen.

From a sustainability perspective, healthcare systems contribute around 5-11% of total carbon emissions. Kidney care is one of the most resource intensive specialties. In addition to energy, haemodialysis and peritoneal dialysis require transportation of patients and personnel to and from facilities, uses large volumes of water and generates significant plastic waste. Overall, current dialysis is not sustainable in the medium term. Primary prevention, early diagnosis and treatment of CKD and transplantation will decrease the need for dialysis, but this will take time and will not prevent the need for dialysis in millions of persons.

There is a need to improve knowledge around the environmental and financial cost of kidney care and social and health outcomes of each patient pathway including using holistic tools such as life cycle assessment (LCA). This knowledge will allow workflow optimizations, organisational transformations and technological innovations across Europe, learning from different clinical sites.

KitNewCare will build a European-wide knowledgebase for sustainability in kidney care, develop and introduce a novel 4 factor database for comprehensive impact analysis, implement optimized processes and organizational transformations in four European clinical sites. It will also pilot innovations from high-tech small- and medium-sized enterprises with focus on kidney care, and establish a network for continuous monitoring, benchmarking, and implementation of sustainable solutions across healthcare sectors. This paper presents the rationale behind selecting kidney disease as a focal point, summarizes the current state of knowledge, and outlines the foundational statement underlying KitNewCare's operational framework.

Key words: Green nephrology, sustainability, environmental burden, kidney replacement therapy, dialysis, kidney care

1.2 Introduction

The environmental impact of the healthcare systems extends beyond physical infrastructure to encompass the people, organisations and industries involved—their systems, culture, and practices.

KitNewCare is a pioneering EU Horizon-funded project, aimed at mitigating the environmental, social, and financial impact of kidney care while optimizing health outcomes. With a focus on sustainability, KitNewCare leverages its international recognition and expertise to collaborate closely with leading healthcare organizations and professionals, ensuring effective communication and the prioritization of sustainable initiatives. By integrating innovative software design and expertise in sustainable healthcare delivery, KitNewCare seeks to revolutionize kidney care practices. This paper presents the rationale behind selecting kidney disease as a focal point, elucidates the current state of knowledge, and outlines the foundational statement underlying KitNewCare's operational framework within this critical domain.

1.3 What is Kitnewcare?

In January 2024, KitNewCare was launched (www.KitNewCare.eu). It is a EU Horizon funded project which will specifically look at ways of reducing kidney care's environmental, social and financial impact while optimising health outcomes. KitNewCare members are internationally recognized leaders in the promotion and implementation of sustainable practices within the healthcare sector (**Table S1**). Emphasizing a patient-centric approach, KitNewCare collaborates closely with healthcare professionals affiliated with organizations such as European Dialysis Transplant Nurse Association/ European Renal Care Association (EDTNA/ERCA), European Kidney Patients' Federation (EKPF), and the European Kidney Health Alliance (EKHA) to ensure effective communication (ICONS) and the prioritization of sustainable initiatives. Moreover, their expertise extends to software design (040 web agency). The Centre for Sustainable Healthcare and Stiftelsen TEM (TEM) are recognised authorities in sustainable healthcare delivery, with a specialized focus on carbon footprint analysis, quality improvement and education. Notably, Trinity College Dublin (TCD) has published numerous Life Cycle Assessments (LCAs) pertaining to healthcare, as well as engaging with social and stakeholder environmental considerations. Within the clinical realm, KitNewCare includes authors who have made significant contributions to the advancement of sustainable nephrology on an international scale. Collaborative efforts with industry

leaders such as Bellco/Mozarc Medical, Baxter, BBraun, Aquaporin, and Bilfinger are underway, aiming to analyze and develop innovative technologies conducive to sustainable healthcare practices.

1.4 The increasing healthcare burden of CKD

There are 850 million people living with kidney disease worldwide and most do not know it[1,]. By 2040, chronic kidney disease (CKD) is anticipated to rank as the fifth leading global cause of premature mortality, largely due to population aging and increasing prevalence of risk factors such as diabetes and hypertension.[1,2] In 2017, 1.2 million people died globally from CKD. The global prevalence (all ages) of CKD between 1990 and 2017 increased by 29.3%.[3,4] and the global all-age mortality rate increased 41.5%.[5] Around 660,000 patients are currently on kidney replacement therapy (KRT) through dialysis or transplantation in Europe, accounting for a government expenditure of 13 billion Euros annually, exclusively for Haemodialysis (HD) and Peritoneal Dialysis (PD).[6,7,8,9]

CKD progresses from risk factors requiring preventive measures, to CKD requiring early diagnosis and treatment to kidney failure (CKD category G5) requiring KRT for survival, although when life expectancy is short, conservative management (i.e., no KRT when needed) is an option. Prevention focuses on managing conditions like diabetes and hypertension and may imply prescription of drugs specifically to delay the onset of CKD. Early detection entails blood (glomerular filtration rate, GFR) and urine (albuminuria) testing in at-risk populations. Early treatment includes lifestyle changes and medications (**figure 1**).

Kidney disease often goes unnoticed for a long time, earning it a reputation of the "silent disease".[10] Moreover, current diagnostic criteria imply that a loss of 50% of kidney function or an increase of albuminuria 5- to 10-fold above normal has already occurred at detection in many cases, illustrating the existence of a blind spot in the current diagnostic approaches to CKD.[11] Additionally, awareness of CKD among non-nephrologists is still low.[12,13] Finally, therapeutic strategies for CKD do not restore the lost kidney function and only slow but do not stop CKD progression.[14] Indeed, KRT does no restore the baseline risk of premature mortality: life expectancy on dialysis may be up to 44 years shorter in young women as compared to the general population. (**Figure 3**).[9,15] These issues should be addressed to reduce mortality and suffering from CKD.

CKD is also associated with adverse outcomes like an increased risk of acute kidney injury (AKI), cardiovascular disease (CVD), infection, cancer and premature all-cause mortality (**Figure 2**).[16] The KDIGO

risk heatmap uses colours to illustrate risk for adverse outcomes[17]. In general, the increase in risk associated to lower kidney function (GFR) or higher evidence of kidney injury (albuminuria) runs in parallel for diverse adverse outcomes. KDIGO heatmap cells in yellow, orange or red represent patients with CKD and increasing risk of adverse health outcomes conveyed low GFR and/or albuminuria. Additionally, some people within the green cells may have CKD despite normal GFR and albuminuria if other evidence of kidney damage is present (e.g., polycystic kidneys on imaging). In natural history, CKD usually evolves from green to yellow to orange to red cells, i.e., is progressive.

1.5 The environmental burden of healthcare

Healthcare systems contribute around 5-11% of our total carbon emissions, among which kidney care is one of the most resource intensive specialties.[18,19,20] They contribute to their environmental impact through energy and water consumption, transportation (patients, staff, goods), consumables, e.g. pharmaceuticals, medical devices, and waste disposal.[21]

Traditionally, efforts to reduce carbon emissions have focused on healthcare energy consumption in buildings and on the supply chain. Around 20% of the healthcare carbon footprint stems from building infrastructure such as heating, air systems, lighting, and water distribution.[22] The other contributors to the healthcare carbon footprint are the supply chain (accounting for up to 75% of the footprint) and healthcare associated travel within the system.[23]

Various reports and initiatives on sustainable healthcare, such as the "Towards a Sustainable Health Workforce in the World Health Organization (WHO) European Region: Framework for Action", have outlined overarching trends, identified barriers, and proposed potential solutions.[24]

Achieving a reduction in global carbon emissions and environmental impact while simultaneously enhancing health outcomes, minimizing social impacts, and managing costs appears achievable in kidney care, based on previous assessments.[25] We need to recognize that healthcare extends beyond physical infrastructure to encompass the people, organisations and industries involved—their systems, culture, and practices.

KitNewCare will specifically look at ways of reducing kidney care's environmental, social and financial impact while optimising health outcomes by applying a novel 4-factor approach.

1.6 Environmental impact of kidney replacement therapy

Kidney care has a disproportionately high environmental burden (in many forms including carbon dioxide equivalent (CO_2-eq) emissions, plastic waste generation, water consumption and others) especially when hemodialysis is required due to considerable water, energy and single-use plastic expenditures and need for frequent patient and personnel transportation resulting in annual per-patient emissions between 3.8 and 10.2 ton CO_2-eq.[26,27]

The global annual water consumption of HD has been estimated at 265 million m^3/year, of which around two-thirds is represented by reverse osmosis reject water discharged into the drain.[28,29]

PD is often considered to have a milder environmental impact than HD because each treatment has lower carbon footprint and water consumption even if this may be partly offset by the water and energy needed to produce dialysate-filled bags and transporting them to multiple private homes periodically (Automated PD (APD) using a cycler has higher per-patient carbon emissions than manual continuous ambulatory PD (CAPD), owing to both higher fluid and consumable requirements and the consequent higher transport impacts.[30] Annual per patient carbon emissions attributable to the manufacture and disposal of PD fluids and consumables were 1.99 ton CO2-eq emissions for APD and 1.245 ton CO2-eq emissions for CAPD. Transport impacts varied depending on the distance between site of manufacture and the home of patients, resulting in a range of total impact of providing PD of 2.35-4.50 ton CO2-eq emissions for APD and 1.455-2.72 ton CO2-eq emissions for CAPD. Recycling of polyvinyl chloride (PVC) could reduce emissions by up to 14% for APD and 30% for CAPD, again depending on the distance between the site of PVC waste generation and the recycling centre

Table 1 summarizes the environmental burden associated with the delivery of KRT, focusing on specific contributors to water consumption, energy consumption, greenhouse gas emissions, pollution, and waste production.

1.7 Social impact of kidney care

The social impacts of kidney care are similar to healthcare and include the impact of product manufacturing and sourcing as well as the social impact of CKD care across society. Many of our products are sourced from

countries with different adherence to occupational safety laws, child labour regulations, and mitigating accident rates, as recently reviewed.[31] There are also potential social costs associated with the distribution, and disposal of kidney care products, including the sourcing of materials, manufacturing processes, distribution, and disposal. The prevalence of CKD disparities across different socio-economic groups implies that social factors may play a role in perpetuating both racial and socioeconomic disparities. These socioeconomic implications of CKD and kidney care pathways may encompass obstacles to employment due to illness, financial burdens on patients and families, and discrepancies in healthcare access across various demographic groups and geographic regions.[32],[33]

1.8 Foundational statement underlying KitNewCare's holistic approach to sustainable kidney care

Based on this background, the foundational statement underlying KitNewCare's holistic approach to sustainable kidney care is:

1.Healthcare extends beyond physical infrastructure to encompass the people, organisations and industries involved—their systems, culture, and practices.

2. Kidney care has a disproportionately high environmental burden, especially when dialysis is required

3. Only a holistic approach to environmental sustainability that assesses health outcomes, together with financial, environmental, and social costs and that encompasses the full life-cycle of items will provide the knowledge foundation to optimize the environmental burden in real world clinical practice

4. Solutions should also be approached holistically, by designing and maintaining databases and networking that allows repeated cycles of quality improvement and benchmarking integrated with technological innovation

1.9 What has already been done

Several organisations support the delivery of sustainable healthcare, including Healthcare without Harm (HCWH), the Health and Environment Alliance (HEAL) and Centre for Sustainable Healthcare (CSH), among others.

HCWH has introduced a Climate Impact Check-up Tool for members of its Global Green and Healthy Hospitals network which allows the estimation of greenhouse gas emissions of all the procurement categories as used by the NHS.[34] However this is only for procurement; it allows environmental assessments, but it does not enable the estimation of financial health outcomes nor social impacts.

HEAL partners with healthcare organizations to advocate for sustainable practices, offering research-based recommendations and guidance. By raising awareness and driving systemic changes, HEAL aims to reduce resource consumption, minimize waste, and improve environmental sustainability while maintaining high standards of patient care.[35]

CSH focuses on integrating sustainability principles into healthcare systems to improve patient care while reducing environmental impact. It develops and promotes sustainable healthcare practices through research, education, and collaboration with healthcare professionals and institutions. Their efforts include initiatives to reduce carbon emissions, minimize waste, and enhance the resilience of healthcare services to environmental challenges.[36]

1.9.1 General guidance on sustainable kidney care

Various initiatives exist already such as the GREEN-K programme of the International Society of Nephrology[37], the UK Kidney Association's Sustainable Kidney Care Committee, the European Renal Association (ERA) Sustainable Nephrology Task Force initiative (https://www.era-online.org/publications/sustainable-nephrology-task-force/)[38] and the Italian Society of Nephrology Green nephrology and eco-dialysis position statement and its recent national survey.[39],[40]

Recommendations within various guidelines to improve the sustainability of kidney care include giving preference to renewable energy sources, recycling uncontaminated paper, glass, and plastic, integrating environmental impact criteria into the assessment checklists for dialysis machines and supplies, and advocating for eco-friendly approaches in the construction of new facilities.

1.9.2 Environmental checklists for kidney care

The EDTNA/ERCA is raising awareness among healthcare professionals about the environmental impact of kidney replacement therapy. It introduced an environmental checklist as a web-based app,[41] available to help kidney care centres assess their environmental performance and potential areas for improvement.

1.9.3 Carbon calculator for kidney care

A free online carbon footprint calculator has been designed for in-centre HD units, measuring the overall footprint and carbon intensity per patient session while pinpointing greenhouse gas emission hotspots. Developed by the Newcastle renal unit and the Sustainable Healthcare Coalition, and supported by AstraZeneca, it addresses the disproportionate resource use and environmental impacts associated with the treatment of kidney failure and enables other centres to assess their own carbon footprints and target areas for change independently.[42]

1.10 In search of holistic solutions: KitNewCare

Despite the recent progress, a more holistic approach is required to increase the odds of success.

KitNewCare plans to build on previous work and to address and mitigate the environmental impacts of kidney care. Recognizing the need for additional structural changes in various areas, KitNewCare brings together all relevant stakeholders (**table S1**) to facilitate change in the environmental burden of kidney care by redesigning the way kidney care is delivered. KitNewCare will perform an EU-wide mapping of the sustainability of kidney care by a 4-impact factor database, that assesses health outcome, environmental impact, social impact, and cost. This EU wide mapping will gather specific data on units of care from all 4 clinical sites, and focus initially on the Peritoneal and Haemodialysis pathways, including all resources used in these areas

These impacts and current knowledge will be used to develop sustainable workflow and organisational optimisations using Plan, Do, Study, Act (PDSA) cycles. The project aims to refine and pilot technological innovations in four clinical sites with the support of small and medium-sized enterprises (SMEs) and large industry. To capture the sustainability benefits of prevention of kidney disease (or its progression), exemplar prevention initiatives in European kidney centres will also be analysed. In addition, KitNewcare aims to develop guidelines and recommendations and an actionable dashboard based on the 4-factor model to monitor and benchmark interventions and healthcare centres across the four outcomes. Decision makers and healthcare providers will be informed about KtiNewCare's insights, solutions and policy recommendations. Finally, a Sustainability Network with associated pilot sites will be setup as a public-private partnership for training purposes and upscaling of sustainability solutions beyond the EU-funding period. The entire process will be informed by intensive stakeholder interaction and a Patient and Public Involvement (PPI) programme to ensure proper design, uptake, dissemination and exploitation. KitNewCare's objectives are described in **table 2**.

1.10.1 Improve knowledge

To make an informed decision to improve kidney care pathways, it is essential to encompass social, economic, environmental costs, and assessing the health outcomes of each pathway. Such an approach is crucial for enhancing the environmental and fiscal sustainability of healthcare systems while upholding the delivery of high-quality care.

At present there is no central database which brings together health outcomes and the triple bottom line (environmental, social and financial cost) at hospital department or treatment/pathway level. Current knowledge includes different levels of knowledge on health outcomes, financial, environmental, and social costs. To create a knowledgebase, academic articles published from 2000 onwards will be reviewed to reflect the advancements in both kidney care and public health systems as well the rising costs over the past 25 years.

KitNewCare will identify and synthesise existing data related to health outcomes across the kidney care pathways utilising two approaches. Firstly, conducting both rapid and systematic reviews to identify relevant peer-reviewed and grey literature reporting health outcomes associated with all care pathways. Search strategies will be developed and refined with input from information specialists, health economists and clinicians. The completeness of reporting and quality of identified studies will be assessed using the 24-item Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist[43]. Secondly, extracting relevant data documented by regional and national registries across numerous European countries. These datasets are collectively contributed to the Annual Report of the Registry of ERA.[44] A partner EU-funded project, PREVENTCKD, has been identified that is already collecting additional information on grey literature in diverse European languages regarding the epidemiology of CKD (https://ekha.eu/preventing-ckd/). These treatment outcomes will be collected and published alongside the information collected from the LCA costs

1.10.1.1 Financial costs

Financial costs associated with each care pathway will be estimated based on vectors of unit costs and the volumes of utilisation. The financial costs research be conducted at the 4 sites where solutions/innovations will subsequently be piloted. A database of unit costs will be developed at all participating clinical sites, utilising administrative data in the first instance. Where unit costs are not available, these will be estimated using both top-down (e.g. the cost of in hospital dialysis) and bottom-up (using product costs, resources etc) approaches.

1.10.1.2 Environmental costs

Environmental research will be focused on specific LCA elements relating the entire kidney care pathway. LCA is the primary method for assessing the environmental impacts of products or processes. The process of conducting an LCA starts with delineating the objectives and boundaries of the system under examination, which typically encompasses all stages of a product's life cycle, from raw material extraction to disposal, either as waste or recycling (**figure 4**). This full life cycle approach is a key difference with usual estimates of environmental impact and provides a more holistic approach to the issue. Subsequently, a comprehensive inventory of material and energy inputs and outputs is compiled, which is then transformed into environmental impacts using characterization factors.[45]

1.10.1.3 Social costs

KitNewCare will analyse two types of social costs. The first point concerns the societal impacts of the manufactured products, such as dialysis solutions, plastic tubing, and disposal bags. For instance, various countries have distinct laws concerning occupational safety, child labour regulations, and accident rates, some more robust than others. KitNewCare will evaluate these social costs using Soca V2, which integrates PSILCA (a novel database for social LCA developed by GreenDelta). PSILCA encompasses extensive generic inventory data for nearly 15,000 industry sectors and commodities, facilitating the calculation and evaluation of social impacts throughout product life cycles and the identification of social hotspots.[46,47]

The second type of social costs relates to the societal outcomes of the patient pathways being considered. These will be determined using patient and public involvement e.g. using questionnaires and focus groups across the four clinical centres.

1.10.2 Improve solutions

1.10.2.1 Improve solutions through a quality improvement (QI) approach

Innovation and implementation of pathway/process/workflow improvements, and adoption of new technologies, can be supported by systematic improvement methodologies which are already applied to other challenges in complex healthcare systems. These include stakeholder engagement, organisational capability building, collaborative process redesign and PDSA cycles, combining these established approaches with a comprehensive framework for evaluating healthcare systems and interventions.[48]

KitNewCare will co-develop and pilot optimised workflow processes and organisational transformations in 4 different clinical sites in 4 European countries using PDSA improvement cycles on identified hotspots and best practices.

1.10.2.2 Improve solutions through a technological innovation approach

Numerous encouraging case studies exist regarding interventions that effectively decrease environmental impact of kidney care.[49] These include advancements in water treatment, such as re-use of reverse osmosis reject water for alternative purposes, optimising the conversion rate of osmosis units, incorporating forward osmosis for the production of dialysate, the reuse of spent dialysate e.g. as a fertiliser or irrigation for agriculture and regeneration of spent dialysate using adsorption systems (applied in portable dialysis devices that are currently in development), forward osmosis or distillation.[50,51,52,53,54] Advancements in waste reduction include use of centralized acid concentrate distribution systems in the dialysis centre, reuse of dialyzers and production of dialysate from tap water at home (for either HD or PD)[55,56,57,58,59], advancements aimed at decreasing energy consumption encompass heat exchangers utilizing the heat from outgoing dialysate to warm incoming dialysate or utilizing the machine's heat for dialysate warming and use of urea, a by-product, either directly as fuel or as a source of hydrogen.[60]

However, up to this point, there has been no systematic testing of multiple interventions at a single site, nor a deliberate comparison and validation of these applications across various sites or in terms of environmental, social, clinical, and cost-related outcomes. Consequently, it remains uncertain which interventions are most effective.

KitNewCare will co-develop and pilot technological innovations working with industries and kidney care providers in 4 different clinical sites. KitNewCare will collaborate with industrial and academic partners and end-users to collectively identify, prioritize, select, integrate, and pilot technologies in a co-designed process. An established 'innovation challenge methodology' will be used to guide this process. This innovation challenge methodology has proven highly effective in promoting technical innovation within healthcare settings. Notable examples include World's Greenest healthcare 2030 and the Nordic White Paper on Sustainable healthcare .[61] The project will test and benchmark the selected innovations in the 4 clinical sites. The impacts of the new technologies on health outcomes will be assessed as well as environmental and social impacts and costs. In this way, KitNewCare aims to provide transferable solutions and tools that may serve as stepping stones for broader, system-wide transformations.

1.10.2.3 Improve solutions through the development of the benchmarking tool

There is currently no established practice for systematically gathering and evaluating data on the environmental and social impact of hospitals, departments, and other healthcare services in Europe.

The Eyefficiency pathway tool estimates the financial and environmental impact and productivity of cataract surgery. However, it does not integrate health outcomes or any other social impacts beyond productivity.[62]

KitNewCare will co-develop and maintain a 4-factor LCA database with social, environmental, health, and financial impacts of kidney care sustainability hotspots. The database will feed into the development of a KitNewCare 4-factor benchmarking dashboard, an online tool which will measure the environmental, social and financial impacts and health outcomes of kidney care centres and their different treatment options, thus empowering them to reduce greenhouse gas emissions, pollution and other environmental impacts and cost, and add social value while maintaining or improving health outcomes.[63]

Once finalized, the tool will allow kidney care centres to monitor and benchmark their impacts over time against other renal centres of similar size and service offer, against centres in their own country or across Europe or against best practice. It will help centres to identify their own environmental and social hotspots and suggest solutions how to address them. Moreover, the information provided by the benchmarking tool will help healthcare organisations and policy makers at national and European level to shift kidney care and other health and care services to more sustainable practices. Without such a tool, sustainability solutions and recommendations are not likely to be implemented and EU-Green Deal objectives in the sustainable healthcare will be difficult.

1.10.3 Improve implementation and upscaling

KitNewCare will combine results into an EU-wide Sustainability Network for continued monitoring, benchmarking, piloting, upscaling and implementing of sustainability solutions and training of healthcare professionals, patients, industry as well as healthcare managers and policy makers.

KitNewCare will embark on the development, delivery, and evaluation of online sustainable kidney care training packages as well as best practice guidance in four languages (English, Spanish, Polish and Italian) drawing from the cutting-edge Sustainable Kidney Care online training modules crafted by the CSH in English. Through this initiative, the programme aims to enhance the capacity of kidney care staff in pilot sites to discern operational changes necessary to tackle unsustainable elements of care. The targeted staff groups for training

encompass nephrologists, technologists, kidney pharmacists, kidney dieticians, and dialysis nurses. These resources will be structured as Continuing Professional Development for established and qualified healthcare practitioners. Educational materials will be made available on an open access online learning platform meticulously designed to facilitate guided self-study, rooted in established theoretical frameworks of effective professional education.

An integrated Dissemination, Exploitation and Communication strategy will maximise impacts in terms of outreach and engagement to support replication, upscaling and uptake. Considering all actors in the kidney care ecosystem and in line with the value proposition analysis of each result, stakeholders will be segmented according to the 'stake' in the project and its outcomes and classified according to two key variables: interest and impact to determine the most appropriate outreach and engagement strategy. A multi-layered approach is pivotal for awareness raising and upscaling at both European level (via online channels, campaigns, media relations and cooperation with European and international associations representing the different target groups) and local level with the support of each partner acting as country representative to liaise with local communities and kidney care ecosystem actors. By intensive stakeholder and end-user involvement in each phase of the project, it will be possible to deliver information that is relevant and usable for external stakeholders and co-develop actionable knowledge translated into multiple communication and educational resources.

1.11 Conclusion

Following its foundational statement, KitNewCare proposes kidney care as a demonstrator and catalyst for developing and testing sustainable healthcare tools, solutions, guidelines, and recommendations. Kidney care, with its considerable disease burden, substantial sustainability footprint, and a clearly defined ecosystem, offers a highly suitable use case. Implementing CKD prevention strategies on top of screening campaigns that allow early diagnosis and treatment of CKD, and transplantation would represent the optimal approach to decrease the need for KRT and its environmental impact.[64] However, once KRT is needed, improving knowledge on sustainability, solutions and upscaling and implementing these solutions are essential to improve the sustainability of KRT.

Moreover, tackling numerous hotspots in kidney care, such as high-water usage, energy consumption, plastic use, and waste production/management, will generate solutions that can be applied to other health disciplines. By the project's conclusion, KitNewCare aims to provide a set of common methodologies and solutions, validated both technically and by end-users across four clinical sites, together with a model for driving implementation at a larger scale.

1.12 Declarations

1.12.1 Ethical approval: It does not apply to the present manuscript

1.12.2 Informed consent to participate. It does not apply to the present manuscript

1.12.3 Competing interests

Alberto Ortiz has received grants from Sanofi and consultancy or speaker fees or travel support from Adviccene, Alexion, Astellas, Astrazeneca, Amicus, Amgen, Boehringer Ingelheim, Fresenius Medical Care, GSK, Bayer, Sanofi-Genzyme, Menarini, Mundipharma, Kyowa Kirin, Lilly, Freeline, Idorsia, Chiesi, Otsuka, Novo-Nordisk, Sysmex and Vifor Fresenius Medical Care Renal Pharma and Spafarma and is Director of the Catedra UAM-Astrazeneca of chronic kidney disease and electrolytes. He has stock in Telara Farma. AO research is also funded by Instituto de Salud Carlos III (ISCIII) FIS/Fondos FEDER RICORS program to RICORS2040 (RD21/0005/0001) funded by European Union – NextGenerationEU, Mecanismo para la Recuperación y la Resiliencia (MRR), COST Action PERMEDIK CA21165, supported by COST (European Cooperation in Science and Technology); PREVENTCKD Consortium Project ID: 101101220 Programme: EU4H DG/Agency: HADEA.

Raymond Vanholder is advisor to AstraZeneca, Glaxo Smith Kline, Fresenius Kabi, Novartis, Kibow, Baxter, Nipro, Fresenius Medical Care and Nextkidney.

Gabriele Donati has received consultancy fees from Medtronic, speaker fees from Mozarc Medical, Fresenius Medical Care, BBraun. He also received grants from Nipro and Alexion.

Karin Gerristen has received consultancy fees from Nextkidney. KG has received funding from the Dutch Growth Fund program NXTGEN HIGHTECH

Mary Lou Wratten is a full-time employee of Mozarc Medical/Bellco.

Brett Duane has received consultancy or speaker fees from Proctor and Gamble, Tepe, private dental clinics, as well as other dental companies.

There are no other competing interests.

1.12.4 Data availability statement: Will be available as Kitnewcare develops

1.12.5 Funding acknowledgement: KitNewCare, Project ID: 101137054, Call: HORIZON-HLTH-2023-CARE-04, Programme: HORIZON. DG/Agency: HADEA. It will cooperate with PREVENTCKD Consortium Project ID: 101101220 Programme: EU4H DG/Agency: HADEA

Figure legends

Figure 1: Natural history of chronic kidney disease and potential for intervention

Figure 2. Prevalence of the different CKD categories presented in the KDIGO risk heatmap.

Figure 3. Years of life expectancy lost in European women on kidney replacement therapy as compared to the general population. Data from ERA[9]

Figure 4. Life cycle assessment (LCA) paradigm for assessing environmental impact.

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1.13 References:

1 Ortiz A; Asociación Información Enfermedades Renales Genéticas (AIRG-E), European Kidney Patients' Federation (EKPF), Federación Nacional de Asociaciones para la Lucha Contra las Enfermedades del Riñón (ALCER), Fundación Renal Íñigo Álvarez de Toledo (FRIAT), Red de Investigación Renal (REDINREN), Resultados en Salud 2040 (RICORS2040), Sociedad Española de Nefrología (SENEFRO) Council, Sociedad Española de Trasplante (SET) Council, Organización Nacional de Trasplantes (ONT). (2021) RICORS 2040: the need for collaborative research in chronic kidney disease. Clin Kidney J. 15(3):372-387. https://doi.org/10.1093/ckj/sfab170

2 Foreman KJ, Marquez N, Dolgert A, Fukutaki K, Fullman N, McGaughey M, Pletcher MA, Smith AE, Tang K, Yuan CW, Brown JC, Friedman J, He J, Heuton KR, Holmberg M, Patel DJ, Reidy P, Carter A, Cercy K, Chapin A, Douwes-Schultz D, Frank T, Goettsch F, Liu PY, Nandakumar V, Reitsma MB, Reuter V, Sadat N, Sorensen RJD, Srinivasan V, Updike RL, York H, Lopez AD, Lozano R, Lim SS, Mokdad AH, Vollset SE, Murray CJL. (2018) Forecasting life expectancy, years of life lost, and all-cause and cause-specific mortality for 250 causes of death: reference and alternative scenarios for 2016-40 for 195 countries and territories. Lancet. 392(10159):2052-2090 https://doi.org/10.1016/S0140-6736(18)31694-5

3 Jager KJ, Kovesdy C, Langham R, Rosenberg M, Jha V, Zoccali C. (2019) A single number for advocacy and communication-worldwide more than 850 million individuals have kidney diseases. Nephrol Dial Transplant. 1;34(11):1803-1805 https://doi.org/10.1093/ndt/gfz174

4 Kovesdy CP. (2022) Epidemiology of chronic kidney disease: an update 2022. Kidney Int Suppl. 12(1):7-11. https://doi.org/10.1016/j.kisu.2021.11.003

5 GBD Chronic Kidney Disease Collaboration. Global, regional, and national burden of chronic kidney disease, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017(2020). Lancet. 395(10225):709-733. https://doi.org/10.1016/S0140-6736(20)30045-3

6 Van der Tol A, Stel VS, Jager KJ, Lameire N, Morton RL, Van Biesen W, Vanholder R. (2020) A call for harmonization of European kidney care: dialysis reimbursement and distribution of kidney replacement therapies. Nephrol Dial Transplant. 1;35(6):979-986. https://doi.org/10.1093/ndt/gfaa035

7 Carriazo S, Aparicio-Madre MI, Tornero-Molina F, Fernández-Lucas M, Paraiso-Cuevas V, González-Parra E, Del Río-Gallegos F, Marques-Vidas M, Alcázar-Arroyo R, Martins-Muñoz J, Sánchez-Villanueva R, Gil-Casares B, Gutiérrez-Martínez E, Martínez-Rubio MP, Ortiz A; (2022) REMER Committee. Impact of different COVID-19 waves on kidney replacement therapy epidemiology and mortality: REMER 2020. Nephrol Dial Transplant. 19;37(11):2253-2263. https://doi.org/10.1093/ndt/gfac234

8 Pippias M, Stel VS, Abad Diez JM, Afentakis N, Herrero-Calvo JA, Arias M, Tomilina N, Bouzas Caamaño E, Buturovic-Ponikvar J, Čala S, Caskey FJ, Castro de la Nuez P, Cernevskis H, Collart F, Alonso de la Torre R, García Bazaga Mde L, De Meester J, Díaz JM, Djukanovic L, Ferrer Alamar M, Finne P, Garneata L, Golan E, González Fernández R, Gutiérrez Avila G, Heaf J, Hoitsma A, Kantaria N, Kolesnyk M, Kramar R, Kramer A, Lassalle M, Leivestad T, Lopot F, Macário F, Magaz A, Martín-Escobar E, Metcalfe W, Noordzij M, Palsson R, Pechter Ü, Prütz KG, Ratkovic M, Resić H, Rutkowski B, Santiuste de Pablos C, Spustová V, Süleymanlar G, Van Stralen K, Thereska N, Wanner C, Jager KJ. (2015) Renal replacement therapy in Europe: a summary of the 2012 ERA-EDTA Registry Annual Report. Clin Kidney J. 8(3):248-61. https://doi.org/10.1093/ckj/sfv014

9 Boerstra B, Boenink R, Astley M, Bonthuis , ElHafeez S, Monzon F, Asberg A, Beckerman P, Bell S, Amenos A, de la Nuez P, ten Dam M, Debska-Slizien A, Gjorgjievski, N, Giudotti R, Helve J, Hommel K, Idrizi A, Indrioason O, Kramer A. (2024). The ERA Registry Annual Report 2021: a summary. Clinical kidney journal, 17(2). https://doi.org/10.1093/ckj/sfad281

10 Webster AC, Nagler EV, Morton RL, Masson P. (2017) Chronic Kidney Disease. Lancet. 25;389(10075):1238-1252. https://doi.org/10.1016/S0140-6736(16)32064-5

11 Sustainable Healthcare. Resources. https://sustainablehealthcare.org.uk/resources Accessed March 21st 2024

12 Carriazo S, Villalvazo P, Ortiz A. (2021) More on the invisibility of chronic kidney disease… and counting. Clin Kidney J. 15(3):388-392. https://doi.org/10.1093/ckj/sfab240

13 Alfano G, Perrone R, Fontana F, Ligabue G, Giovanella S, Ferrari A, Gregorini M, Cappelli G, Magistroni R, Donati G. (2022) Rethinking Chronic Kidney Disease in the Aging Population. Life (Basel). 12(11):1724. https://doi.org/10.3390/life12111724

14 Ruiz-Ortega M, Rayego-Mateos S, Lamas S, Ortiz A, Rodrigues-Diez RR. (2020) Targeting the progression of chronic kidney disease. Nat Rev Nephrol. 16(5):269-288. https://doi.org/10.1038/s41581-019-0248-y

15 Cordero L, Ortiz A. (2024) Decreased life expectancy: a health outcome not corrected by kidney replacement therapy that emphasizes the need for primary prevention of CKD. Clin Kidney J. 17(5) https://doi.org/10.1093/ckj/sfae053

16 Perez-Gomez MV, Bartsch LA, Castillo-Rodriguez E, Fernandez-Prado R, Fernandez-Fernandez B, Martin-Cleary C, Gracia-Iguacel C, Ortiz A. (2019) Clarifying the concept of chronic kidney disease for non-nephrologists. Clin Kidney J. 12(2):258-261. https://doi.org/10.1093/ckj/sfz007

17 KDIGO 2024 Clinical Practice Guideline for the Evaluation and Management of CKD. (2024) Kidney Int;105(4S),S117–S314.

18 Lenzen M, Malik A, Li M, Fry J, Weisz H, Pichler PP, Chaves LSM, Capon A, Pencheon D. (2020) The environmental footprint of health care: a global assessment. Lancet Planet Health. 4(7):e271-e279. https://doi.org/10.1016/S2542-5196(20)30121-2\

19 Vanholder R, Conway PT, Gallego D, Scheres E, Wieringa F. (2023) The European Kidney Health Alliance (EKHA) and the Decade of the KidneyTM. Nephrol Dial Transplant. 38(5):1113-1122. https://doi.org/10.1093/ndt/gfac211

20 Wieringa F, Søndergaard H, Ortiz A. (2023) Coordinating efforts to optimize next-generation kidney replacement therapies: the European Kidney Health Alliance Work Group 'Breakthrough Innovation'. Clin Kidney J. 16(6):885-890. https://doi.org/10.1093/ckj/sfad016

21 GBD 2019 Risk Factors Collaborators. (2020) Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet. 396(10258):1223-1249. https://doi.org/10.1016/S0140-6736(20)30752-2

22 Net Zero Carbon Healthcare guide. https://www.arup.com/-/media/arup/files/publications/n/net-zero-carbon-HC-guide.pdf Accessed January 15th 2024

23 Faculty Interest Group Sustainable Development of Public Health Special. The NHS: Carbon Footprint. https://www.fph.org.uk/media/3126/k9-fph-sig-nhs-carbon-footprint-final.pdf Accessed January 15th 2024

24 OECD. Health in the 21st Century. Putting Data to Work for Stronger Health Systems https://www.oecd.org/publications/health-in-the-21st-century-e3b23f8e-en.htm Accessed January 15th 2024

25 Sustainable HC. Cumulative Savings from Green Nephrology Innovations - poster presented at RA-BTS Congress 201. https://sustainableHC.org.uk/file/295/download?token=ljhRclNx Accessed January 15th 2024

26 Connor A, Lillywhite R, Cooke MW. (2011) The carbon footprints of home and in-center maintenance hemodialysis in the United Kingdom. Hemodial Int. 15(1):39-51 https://doi.org/10.1111/j.1542-4758.2010.00523.x

27 Lim AE, Perkins A, Agar JW. (2013) The carbon footprint of an Australian satellite haemodialysis unit. Aust Health Rev. 37(3):369-374. https://doi.org/10.1071/AH13022

28 Ben Hmida M, Mechichi T, Piccoli GB, Ksibi M. (2023) Water implications in dialysis therapy, threats and opportunities to reduce water consumption: a call for the planet. Kidney Int. 104(1):46-52. https://doi.org/10.1016/j.kint.2023.04.008.

29 Molano-Triviño A, Wancjer B, Neri MM, Karopadi AN, Rosner M, Ronco C. (2018) Blue Planet dialysis: novel water-sparing strategies for reducing dialysate flow. Int J Artif Organs. 41(1):3-10. https://doi.org/10.5301/ijao.5000660

[30] McAlister S, Talbot B, Knight J, Blair S, McGain F, McDonald S, Nelson C, Knight R, Barraclough KA. The Carbon Footprint of Peritoneal Dialysis in Australia. J Am Soc Nephrol. 2024 Aug 1;35(8):1095-1103. doi: 10.1681/ASN.0000000000000361. Epub 2024 Apr 26.

31 Bhutta MF. (2008) Fair and ethical trade in health procurement. Lancet. 6;372(9654):1935-7. https://doi.org/10.1016/S0140-6736(08)61826-7.

32 Norton JM, Grunwald L, Banaag A, Olsen C, Narva AS, Marks E, Koehlmoos TP. (2021) Racial and Socioeconomic Disparities in CKD in the Context of Universal Health Care Provided by the Military Health System. Kidney Med. 4(1):100381. https://doi.org/10.1016/j.xkme.2021.08.015.

33 van Manen JG, Korevaar JC, Dekker FW, Reuselaars MC, Boeschoten EW, Krediet RT (2001) NECOSAD Study Group. Netherlands Cooperative Study on Adequacy of Dialysis. Changes in employment status in end-stage renal disease patients during their first year of dialysis. Perit Dial Int. 21(6):595-601.

34 Healthcare Without Harm. Global Green and Healthy Hospitals' Climate Impact Check-up Tool. https://greenhospitals.org/checkup Accessed March 21st 2024

35 HEAL. https://www.env-health.org/issues/health-diseases. Accessed March 21st 2024

36 Sustainable healthcare. https://sustainablehealthcare.org.uk. Accessed March 21st 2014

37 Stigant CE, Barraclough KA, Harber M, Kanagasundaram NS, Malik C, Jha V, Vanholder RC (2023) Our Shared Responsibility – The Urgent Necessity of Global Environmentally Sustainable Kidney Care, Kidney International https://doi.org/10.1016/j.kint.2022.12.015

38 ERA Sustainable Nephrology Task Force initiative. https://www.era-online.org/publications/sustainable-nephrology-task-force/#:~:text=The%20main%20purpose%20of%20the,term%20to%20achieve%20specific%20tasks Accessed March 21st 2024

39 Piccoli GB, Cupisti A, Aucella F, Regolisti G, Lomonte C, Ferraresi M, Claudia D, Ferraresi C, Russo R, La Milia V, Covella B, Rossi L, Chatrenet A, Cabiddu G, Brunori G (2020) On the Behalf of Conservative treatment, Physical activity and Peritoneal dialysis project groups of the Italian Society of Nephrology. Green nephrology and eco-dialysis: a position statement by the Italian Society of Nephrology. J Nephrol. 33(4):681-698. https://doi.org/10.1007/s40620-020-00734-z

40 Alfano G, Bergesio F, Lombardi M, Piccoli GB, Salomone M, Bonucchi D, Cusinato S, Colturi C, Quintaliani P, Santoro A, D'Alessandro C, Ciciani AM (2024) Project Group on Green Nephrology of the Italian Society of Nephrology. Eco-dialysis in Italy: where are we? National survey on the eco-sustainability of dialysis across Italian dialysis centers. J Nephrol. https://doi.org/10.1007/s40620-023-01882-8

41 EDTNAERCA. Environmental checklist. https://www.edtnaerca.org/environmental-checklist. Accessed March 21st 2024

42 UK Kidney. Sustainable kidney care committee. https://ukkidney.org/sustainable-kidney-care-committee. Accessed March 21st 2024

43 Husereau D, Drummond M, Augustovski F, de Bekker-Grob E, Briggs AH, Carswell C, Caulley L, Chaiyakunapruk N, Greenberg D, Loder E, Mauskopf J, Mullins CD, Petrou S, Pwu RF, Staniszewska S; (2022) CHEERS 2022 ISPOR Good Research Practices Task Force. Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) Statement: Updated Reporting Guidance for Health Economic Evaluations. https://doi.org/10.1111/1471-0528.17012

44 European Renal Association. ERA Registry Annual Report. 2020. https://www.era-online.org/wp-content/uploads/2022/12/ERA-Registry-Annual-Report2020.pdf. Accessed 14th March 2024

45 ISO standards 14040. https://www.iso.org/standard/37456.html.Accessed 14th March 2024

46 Soca v2. Available at https://www.openlca.org/soca-v2-new-version. Accessed 14th March 2024

47 PSILCA. https://psilca.net. Accessed 14th March 2024

48 Ogrinc G, Dolansky M, Berman AJ, Chambers DA, Davies L. (2021) Different approaches to making and testing change in HC. BMJ. 17;374:n1010. http://doi.org/10.1136/bmj.n1010

49 Centre for Sustainable HC. Resources. https://sustainablehealthcare.org.uk/resources.

Accessed 14th March 2024

50 Agar JW, Simmonds RE, Knight R, Somerville CA. Using water wisely: New, affordable, and essential water conservation practices for facility and home hemodialysis. Hemodial Int. 2009 Jan;13(1):32-7. https://doi.org/10.1111/j.1542-4758.2009.00332.x

51 Next Kidney. https://nextkidney.com/ Accessed 14th March 2024

52 Mauerer M, Rocksch T, Dannehl D, Schuch I, Mewis I, Förster N, Ulrichs C, Schmidt U. (2023) Replacing Mineral Fertilizer with Nitrified Human Urine in Hydroponic Lettuce (Lactuca sativa L.) Production. Sustainability. 15:10684. Available from: https://doi.org/10.3390/su151310684.

53 Filtration Separation. Aquaporin membranes cut hemodialysis water costs. https://www.filtsep.com/content/news/aquaporin-membranes-cut-hemodialysis-water-costs.

Accessed 14th March 2024

54 Dou P, Donato D, Guo H, Zhao S, He T. (2020) Recycling water from spent dialysate by osmotic dilution: Impact of urea rejection of forward osmosis membrane on hemodialysis duration. Desalination. 15; 496:114605. https://doi.org/10.1016/j.desal.2020.114605

55 ERA. Towards Green Practice. Good Practice guide. https://www.era-online.org/wp-content/uploads/2023/09/SFNDT_EN_guide-complet_VF_HD.pdf

Accessed 14th March 2024

56 Duygan B, Udert K, Remmele A, and McArdell C. (2021) Removal of pharmaceuticals from human urine during storage, aerobic biological treatment, and activated carbon adsorption to produce a safe fertilizer Resources, Conservation and Recycling 166:105341. doi: https://doi.org/10.1016/j.resconrec.2020.105341.

57 Bradford Teaching Hospitals NHS Foundation Trust. Centralized distribution of acid for hemodialysis. Mapping Greener HC. 2011. https://map.sustainableHC.org.uk/bradford-teaching-hospitals-nhs-foundation-trust/central-delivery-acid-haemodialysis

58 Basile C, Davenport A, Mitra S, Pal A, Stamatialis D, Chrysochou C, Kirmizis D. (2021) Frontiers in hemodialysis: Innovations and technological advances. Artif Organs. 45(2):175-182. https://doi.org/10.1111/aor.13798.

59 Central Delivery of Acid for Haemodialysis. Available at https://networks.sustainablehealthcare.org.uk/resources/central-delivery-acid-haemodialysis. Accessed 14th March 2024

60 Zhu B, Liang Z, and Zou R. (2020) Designing Advanced Catalysts for Energy Conversion Based on Urea Oxidation Reaction. Nano Micro Small. https://doi.org/10.1002/smll.201906133.

61 Green innovation group. Health Use Case for Nordic Innovation https://www.greeninnovationgroup.com/husca. Accessed 14th March 2024

62 Eye efficiency tool. https://eyefficiency.org. Accessed 14th March 2024

63 Thiel C L et al. (2020) Utilizing off-the-shelf LCA methods to develop a ‘triple bottom line’ auditing tool for global cataract surgical services. https://doi.org/10.1016/j.resconrec.2020.104805.

64 Ortiz A, Quiroga B, Díez J, Escalada San Martín FJ, Ramirez L, Pérez Maraver M, Martínez-Berganza Asensio ML, Arranz Arija JÁ, Alvarez-Ossorio Fernández JL, Córdoba R, Brotons Muntó F, Cancelo Hidalgo MJ, Carles Reverter J, Plasencia-Rodríguez C, Carretera Gómez J, Guijarro C, Freijo Guerrero MDM, de Sequera P. (2023)The Spanish Scientific Societies before the ESC 2021 guidelines on vascular disease prevention: Generalizing the measurement of albuminuria to identify vascular risk and prevent vascular disease. Nefrologia (Engl Ed). 2023 Mar-Apr;43(2):245-250. https://doi.org/10.1016/j.nefroe.2023.06.005

Figure 2

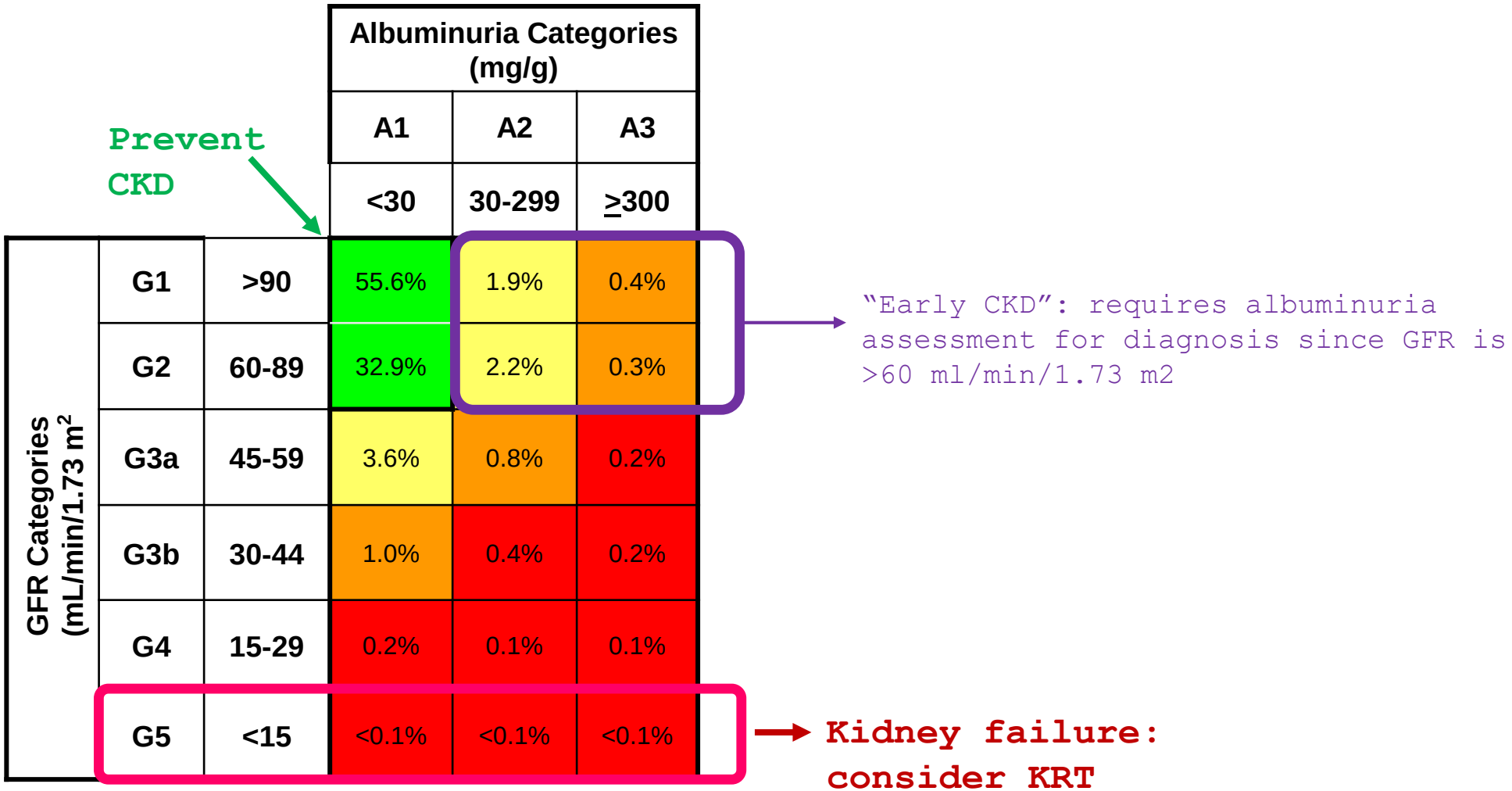

Figure 3

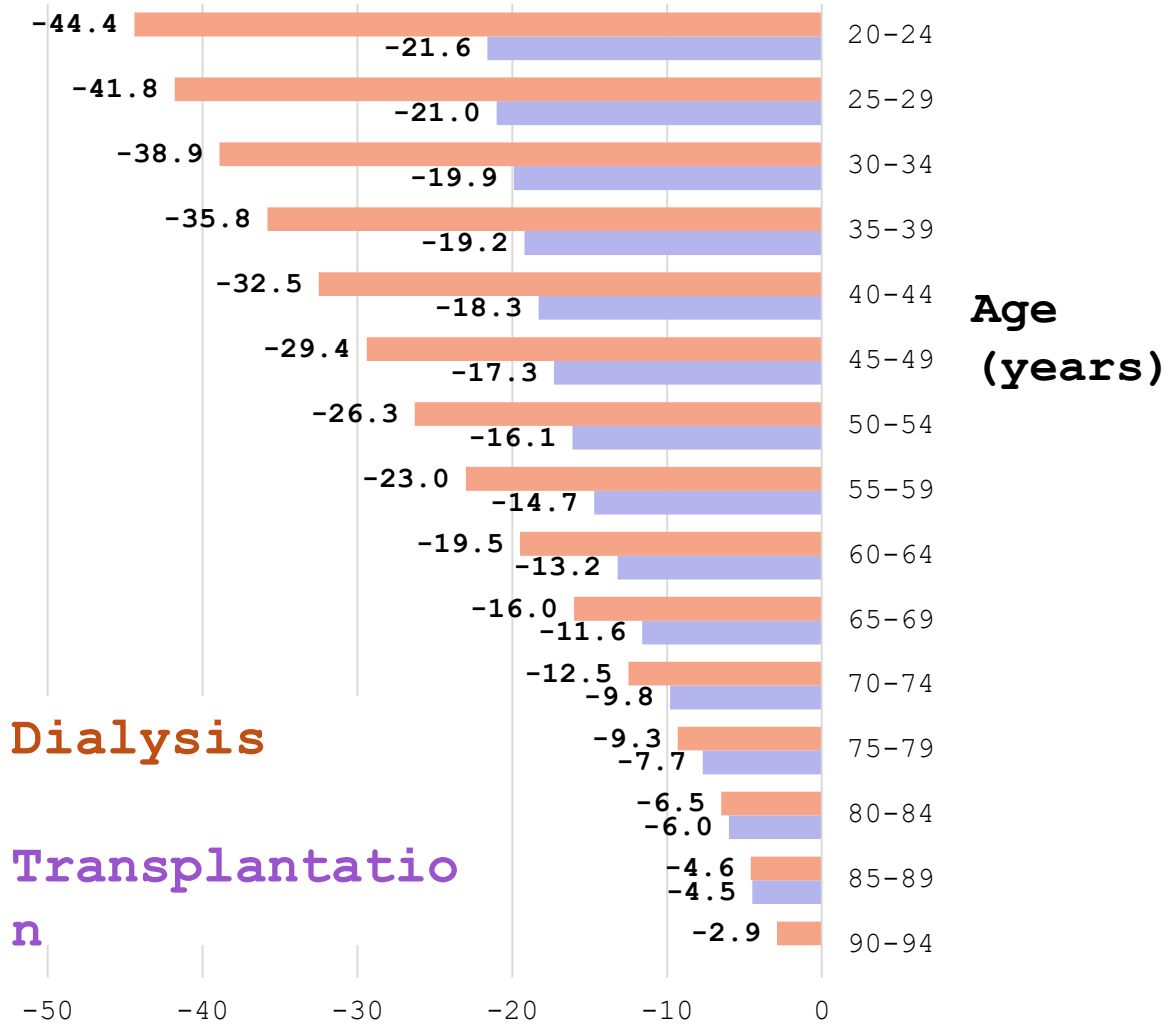

Figure 4

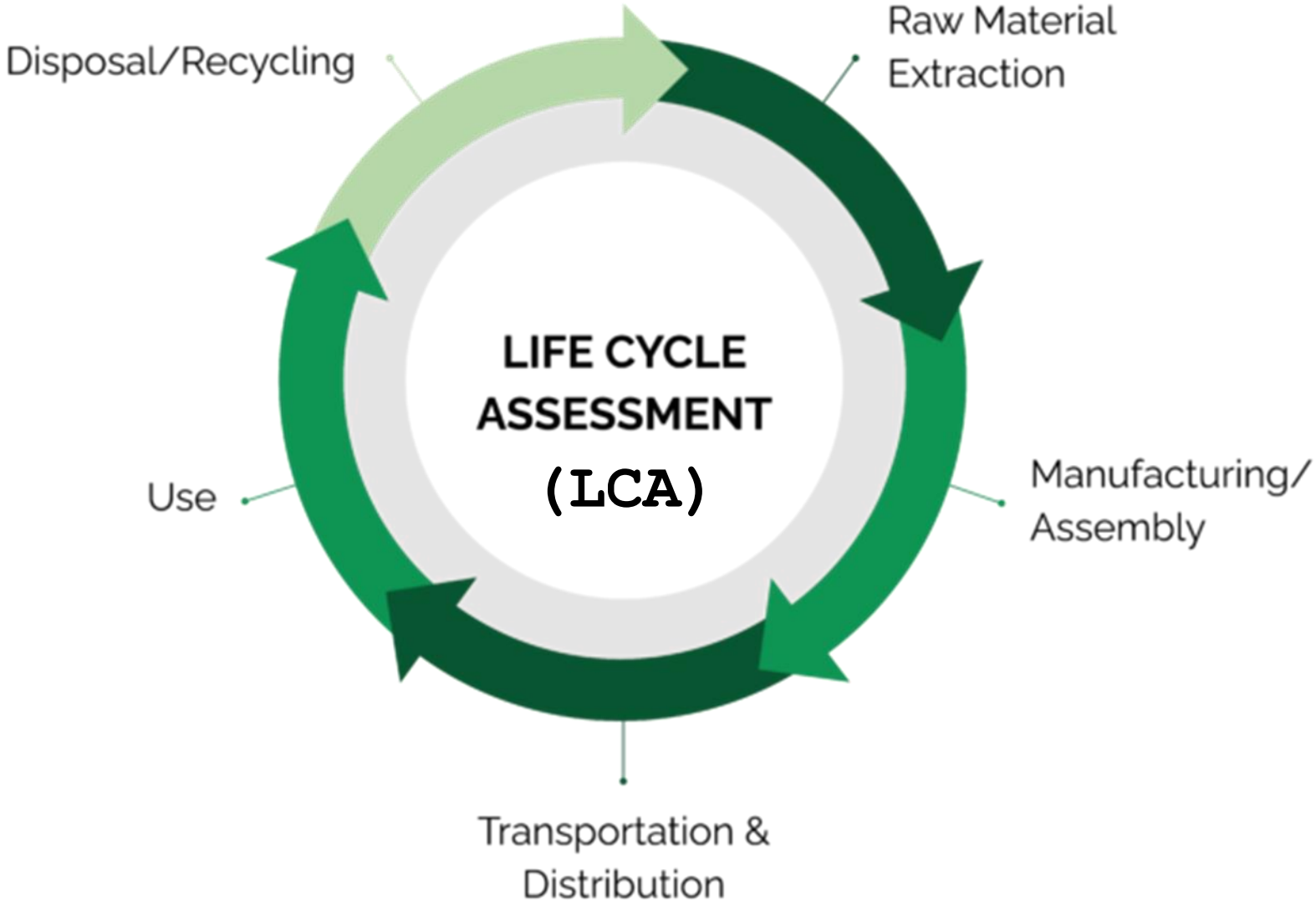

Table S1. KitNewCare partners

Organisation	Representing	Country
Centre for Sustainable Health Care	Sustainable Healthcare	UK
EKHA (European Kidney Health Alliance)	Patient/Healthcare representative	Europe-wide
EDTNA/ERCA (The European Dialysis and Transplant Nurses Association/European Renal Care Association)	Healthcare representative	Europe-wide
Bellco/Mozarc Medical	Biomedical industry	Italy
Baxter	Biomedical industry	Global
BBraun	Biomedical industry	Global
JAIHW (Jönköping University)	Academic partner	Sweden
EKPF (European Kidney Patients Federation)	Patient representative	Europe-wide
040 Web agency	Software partner	Sweden
Aquaporin	Biomedical industry	Denmark
Bilfinger	Biomedical industry	Netherlands
Tem Foundation	Academic partner	Sweden
Unimore University	University Medical Centre	Italy
Fondazione ICONS	Non-profit organization, maximisation of research impacts, Dissemination, Exploitation and Communication	Italy
WUM (Medical University of Warsaw)	Clinical Site	Poland
IIS-FJD (Instituto de investigación Sanitaria Fundacion Jimenez Diaz)	University Medical Centre	Spain
UMCU (Utrecht Medical Centre University)	University Medical Centre	Netherlands
TCD (Trinity College Dublin)	Coordinator Clinical Site, Academic partner	Ireland

Improving the sustainability and quality of kidney health care through life cycle assessments, quality improvement, education and technical innovations: the KitNewCare approach

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1.1 Abstract

The European Union (EU)-funded KitNewCare consortium aims to create and manage a comprehensive EU-wide programme focusing on sustainability in Kidney Care.

Around 850 million people have chronic kidney disease (CKD) worldwide and by 2030 6 million will need kidney replacement therapy, mainly haemodialysis. As the world population gets older, projections for the end of the century worsen.

From a sustainability perspective, healthcare systems contribute around 5-11% of total carbon emissions. Kidney care is one of the most resource intensive specialties. In addition to energy, haemodialysis and peritoneal dialysis require~~s~~ transportation of patients and personnel to and from facilities, uses large volumes of water and generates significant plastic waste. Overall, current dialysis is not sustainable in the medium term. Primary prevention, early diagnosis and treatment of CKD and transplantation will decrease the need for dialysis, but this will take time and will not prevent the need for dialysis in millions of persons.

There is a need to improve knowledge around the environmental and financial cost of kidney care and social and health outcomes of each patient pathway including using holistic tools such as ~~4 factor~~ life cycle assessment (~~4~~ LCA). This knowledge will allow workflow optimizations, organisational transformations and technological innovations across Europe, learning from different clinical sites.

KitNewCare will build a European-wide knowledgebase for sustainability in kidney care, develop and introduce a novel 4 factor ~~LCA~~ database for comprehensive impact analysis, implement optimized processes and organizational transformations in four European clinical sites. It will also pilot innovations from high-tech small- and medium-sized enterprises with focus on kidney care, and establish a network for continuous monitoring, benchmarking, and implementation of sustainable solutions across healthcare sectors. This paper presents the rationale behind selecting kidney disease as a focal point, summarizes the current state of knowledge, and outlines the foundational statement underlying KitNewCare's operational framework.

Key words: Green nephrology, sustainability, environmental burden, kidney replacement therapy, dialysis, kidney care

1.2 Introduction

The environmental impact of the ~~H~~healthcare ~~(HC)~~ systems extends beyond physical infrastructure to encompass the people, organisations and industries involved—their systems, culture, and practices.

KitNewCare is a pioneering EU Horizon-funded project, aimed at mitigating the environmental, social, and financial impact of kidney care while optimizing health outcomes. With a focus on sustainability, KitNewCare leverages its international recognition and expertise to collaborate closely with leading healthcare organizations and professionals, ensuring effective communication and the prioritization of sustainable initiatives. By integrating innovative software design and expertise in sustainable healthcare delivery, KitNewCare seeks to revolutionize kidney care practices. This paper presents the rationale behind selecting kidney disease as a focal point, elucidates the current state of knowledge, and outlines the foundational statement underlying KitNewCare's operational framework within this critical domain.

1.3 What is~~o are~~ Kitnewcare?

In January 2024, KitNewCare was launched (www.KitNewCare.eu). It is a EU Horizon funded project which will specifically look at ways of reducing kidney care's environmental, social and financial impact while optimising health outcomes. KitNewCare members are internationally recognized leaders in the promotion and implementation of sustainable practices within the healthcare sector (**Table S1**). Emphasizing a patient-centric approach, KitNewCare collaborates closely with healthcare professionals affiliated with organizations such as European Dialysis Transplant Nurse Association/ European Renal Care Association (EDTNA/ERCA), European Kidney Patients' Federation (EKPF), and the European Kidney Health Alliance (EKHA) to ensure effective communication (ICONS) and the prioritization of sustainable initiatives. Moreover, their expertise extends to software design (040 web agency). The Centre for Sustainable Healthcare and Stiftelsen TEM (TEM) are recognised authorities in sustainable healthcare delivery, with a specialized focus on carbon footprint analysis, quality improvement and education. Notably, Trinity College Dublin (TCD) has published numerous Life Cycle Assessments (LCAs) pertaining to healthcare, as well as engaging with social and stakeholder environmental considerations. Within the clinical realm, KitNewCare includes authors who have made significant contributions to the advancement of sustainable nephrology on an international scale. Collaborative efforts with industry

leaders such as Bellco/Mozarc Medical, Baxter, BBraun, Aquaporin, and Bilfinger are underway, aiming to analyze and develop innovative technologies conducive to sustainable healthcare practices.

1.4 The increasing healthcare burden of CKD

There are 850 million people living with ~~chronic~~ kidney disease ~~(CKD)~~ worldwide and most do not know it[1,]. By 2040, chronic kidney disease (CKD) is anticipated to rank as the fifth leading global cause of premature mortality, largely ~~attributed~~ due to population aging and increasing prevalence of risk factors such as diabetes and hypertension~~to rising life expectancy and heightened prevalence of diabetes, a primary CKD risk factor~~.[1,2] In 2017, 1.2 million people died globally from CKD. The global prevalence (all ages) of CKD between 1990 and 2017 increased by 29.3%.[3,4] and the global all-age mortality rate ~~from CKD~~ increased 41.5% ~~between the same years~~.[5] ~~Further increases are expected due to population aging and increasing prevalence of risk factors such as diabetes and hypertension.~~ Around 660,000 patients ~~undergo~~ are currently on kidney replacement therapy (KRT) through dialysis or transplantation in Europe, accounting for a government expenditure of 13 billion Euros annually, exclusively for Haemodialysis (HD) and Peritoneal Dialysis (PD).[6,7,8,9]

CKD progresses from risk factors requiring preventive measures, to CKD requiring early diagnosis and treatment to kidney failure (CKD category G5) requiring KRT for survival, although when life expectancy is short, conservative management (i.e., no KRT when needed) is an option. Prevention focuses on managing conditions like diabetes and hypertension and may imply prescription of drugs specifically to delay the onset of CKD. Early detection ~~through~~ entails blood ~~Early detection of CKD through blood~~ (glomerular filtration rate, GFR) ~~and urine (albuminuria) tests is crucial to improve outcomes.~~ and urine (albuminuria) testing in at-risk populations~~s is crucial~~. Early t~~T~~reatment includes lifestyle changes and~~,~~ medications~~, and, in advanced cases, transplantation or dialysis for improved survival and quality of life~~ (**figure 1**).

Kidney disease often goes unnoticed for a long time, earning it a reputation of the "silent disease".[10] Moreover, current diagnostic criteria imply that a loss of 50% of kidney function or an increase of albuminuria 5- to 10-fold above normal has already occurred at detection in many cases, illustrating the existence of a blind spot in the current diagnostic approaches to CKD.[11] Additionally, awareness of CKD among non-nephrologists is still low.[12,13] Finally, therapeutic strategies for CKD do not restore the lost kidney function and only slow but do not stop CKD progression.[14] Indeed, KRT does no restore the baseline risk of premature mortality: life expectancy

on dialysis may be up to 44 years shorter in young women as compared to the general population. (**Figure 3**).[9,15] These issues should be addressed to reduce ~~As a consequence, the health burden of CKD is increasing both in terms of~~ mortality and ~~of~~ suffering from CKD.

~~Kidney failure, the most advanced stage of CKD, is associated with adverse outcomes and requires KRT, including HD, PD or transplantation (**figure 1**) for survival. When life expectancy is short, conservative management (i.e., no KRT when needed) is an option.~~

CKD is also associated with adverse outcomes like an increased risk of acute kidney injury (AKI), cardiovascular disease (CVD), infection, cancer and premature all-cause mortality (**Figure 2**).[16] The KDIGO risk heatmap uses colours to illustrate risk for adverse outcomes[17]. In general, the increase in risk associated to lower kidney function (~~glomerular filtration rate,~~ GFR) or higher evidence of kidney injury (albuminuria) runs in parallel for diverse adverse outcomes ~~ranging from premature death to need for KRT~~. KDIGO heatmap c~~C~~ells in yellow, orange or red represent patients with CKD ~~because of low GFR and/or albuminuria~~ and increasing risk of adverse health outcomes conveyed low GFR and/or albuminuria. Additionally, some people within the green cells may have CKD despite normal GFR and albuminuria if other evidence of kidney damage is present (e.g., polycystic kidneys on imaging). In natural history, CKD usually evolves from green to yellow to orange to red cells, i.e., is progressive. ~~If premature death does not occur, it may eventually evolve to kidney failure, potentially requiring KRT. The kidney failure outcome is more common in younger people and premature death prior to kidney failure is more common in older people. Prevention focuses on managing conditions like diabetes and hypertension and may imply prescription of drugs specifically to delay the onset of CKD in people who do not yet have CKD. Early detection of CKD through blood (GFR) and urine (albuminuria) tests is crucial to improve outcomes. Once CKD is established, treatment includes lifestyle changes, medications, and, in advanced cases, KRT for improved survival and quality of life. Despite this, KRT does no restore the baseline risk of premature mortality: life expectancy on dialysis may be up to 44 years shorter in young women as compared to the general population. (**Figure 3**).[9,18]~~

1.5 The environmental burden of healthcare

Healthcare ~~(HC)~~ systems contribute around 5-11% of our total carbon emissions, among which kidney care is one of the most resource intensive specialties.[19,20,21] They~~HC systems~~ contribute to their environmental impact

through energy and water consumption, transportation (~~of~~ patients, staff, ~~and~~ goods), consumables, e.g. pharmaceuticals, medical devices, and waste disposal.[22]

Traditionally, efforts to reduce carbon emissions have focused on ~~HC~~healthcare energy consumption in buildings and on the supply chain. Around 20% of the ~~HC~~healthcare carbon footprint stems from building infrastructure such as heating, air systems, lighting, and water distribution.[23] The other contributors to the ~~HC~~healthcare carbon footprint are the supply chain (accounting for up to 75% of the footprint) and ~~HC~~healthcare associated travel within the system.[24]

Various reports and initiatives on sustainable ~~HC~~h~~H~~ealthcare, such as the "Towards a Sustainable Health Workforce in the World Health Organization (WHO) European Region: Framework for Action", have outlined overarching trends, identified barriers, and proposed potential solutions.[25]

Achieving a reduction in global carbon emissions and environmental impact while simultaneously enhancing health outcomes, minimizing social impacts, and managing costs appears achievable in kidney care, based on previous assessments.[26] We need to recognize that ~~HC~~healthcare extends beyond physical infrastructure to encompass the people, organisations and industries involved—their systems, culture, and practices.

KitNewCare will specifically look at ways of reducing kidney care's environmental, social and financial impact while optimising health outcomes by applying a novel 4-factor ~~LCA~~ approach.

1.6 Environmental impact of kidney replacement therapy

Kidney care has a disproportionately high environmental burden (in many forms including carbon dioxide equivalent ~~emissions~~(CO_2-eq) emissions, plastic waste generation, water consumption and others) especially when hemodialysis is required due to considerable water, energy and single-use plastic expenditures and need for frequent patient and personnel transportation resulting in annual per-patient emissions between 3.8 and 10.2 ton CO_2-eq.[27,28]

The global annual water consumption of HD has been estimated at 265 million m^3/year, of which around two-thirds is represented by reverse osmosis reject water discharged into the drain.[29,30]

Although PD is often considered to have a milder environmental impact than HD because each treatment has lower carbon footprint and water consumption, thi even if this may be partly offset by the water and energy needed to produce dialysate-filled bags and transporting them to multiple private homes periodically(), likely leading to an overall environmental impact similar to HD.[31] Automated PD (APD) using a cycler has higher per-patient carbon emissions than manual continuous ambulatory PD (CAPD), owing to both higher fluid and consumable requirements and the consequent higher transport impacts (PMID: 38671537).

Annual per patient carbon emissions attributable to the manufacture and disposal of PD fluids and consumables were 1,.992 tonkg CO2 equivalent emissions for APD and 1,.245 kgton CO2 equivalent emissions for CAPD. Transport impacts varied depending on the distance between site of manufacture of PD fluids and consumables and the home state of the patients, . As a resulting , the in a range of total impact of providing PD also differed by Australian state, ranging fromof 2,.350-4,.50 ton3 kg CO2 equivalent emissions for APD and from 1,.455-2,.72 ton16 kg CO2 equivalent emissions for CAPD. Recycling of polyvinyl chloride (PVC) could reduce emissions by up to 14% per cent for APD and 30% per cent for CAPD, again depending on the distance between the site of PVC waste generation and the recycling centre

Table 1 summarizes the environmental burden associated with the delivery of KRT, focusing on specific contributors to water consumption, energy consumption, greenhouse gas emissions, pollution, and waste production.

1.7 Social impact of kidney care

The social impacts of kidney care are similar to HC healthcare and include the impact of product manufacturing and sourcing as well as the social impact of CKD care across society. Many of our products are sourced from countries with different adherence to occupational safety laws, child labour regulations, and mitigating accident rates, as recently reviewed.[32] There are also potential social costs associated with the distribution, and disposal of kidney care products, including the sourcing of materials, manufacturing processes, distribution, and disposal. The prevalence of CKD disparities across different socio-economic groups implies that social factors may play a role in perpetuating both racial and socioeconomic disparities. These socioeconomic implications of CKD and kidney care pathways may encompass obstacles to employment due to illness, financial burdens on patients and

Commented [ao1]: Grafals M, Sanchez R. The environmental impact of dialysis vs transplantation. Am J Transplant 2016; 16: C74 https://atcmeetingabstracts.com/abstract/the-environmental-impact-of-dialysis-vs-transplantation/

families, and discrepancies in healthcare ~~HC~~ access across various demographic groups and geographic regions.[33,34]

1.8 Foundational statement underlying KitNewCare's holistic approach to sustainable kidney care

Based on this background, the foundational statement underlying KitNewCare's holistic approach to sustainable kidney care is:

1.~~H~~ealthcare ~~HC~~ extends beyond physical infrastructure to encompass the people, organisations and industries involved—their systems, culture, and practices.

2. Kidney care has a disproportionately high environmental burden, especially when dialysis is required

3. Only a holistic approach to environmental sustainability that assesses health outcomes, together with financial, environmental, and social costs and that encompasses the full life-cycle of items will provide the knowledge foundation to optimize the environmental burden in real world clinical practice

4. Solutions should also be approached holistically, by designing and maintaining databases and networking that allows repeated cycles of quality improvement and benchmarking integrated with technological innovation

1.9 What has already been done

Several organisations support the delivery of sustainable healthcare, including Healthcare without Harm (HCWH), the Health and Environment Alliance (HEAL) and Centre for Sustainable Healthcare (CSH), among others.

HCWH has introduced a Climate Impact Check-up Tool for members of its Global Green and Healthy Hospitals network which allows the estimation of greenhouse gas emissions of all the procurement categories as used by the NHS.[35] However this is only for procurement; it allows environmental assessments, but it does not enable the estimation of financial health outcomes nor social impacts.

HEAL partners with healthcare organizations to advocate for sustainable practices, offering research-based recommendations and guidance. By raising awareness and driving systemic changes, HEAL aims to reduce

resource consumption, minimize waste, and improve environmental sustainability while maintaining high standards of patient care.[36]

CSH focuses on integrating sustainability principles into healthcare systems to improve patient care while reducing environmental impact. It develops and promotes sustainable healthcare practices through research, education, and collaboration with healthcare professionals and institutions. Their efforts include initiatives to reduce carbon emissions, minimize waste, and enhance the resilience of healthcare services to environmental challenges.[37]

1.9.1 General guidance on sustainable kidney care

Various initiatives exist already such as the GREEN-K programme of the International Society of Nephrology[38], the UK Kidney Association's Sustainable Kidney Care Committee, the European Renal Association (ERA) Sustainable Nephrology Task Force initiative (https://www.era-online.org/publications/sustainable-nephrology-task-force/)[39] and the Italian Society of Nephrology Green nephrology and eco-dialysis position statement and its recent national survey.[40],[41]

Recommendations within various guidelines to improve the sustainability of kidney care include giving preference to renewable energy sources, recycling uncontaminated paper, glass, and plastic, integrating environmental impact criteria into the assessment checklists for dialysis machines and supplies, and advocating for eco-friendly approaches in the construction of new facilities.

1.9.2 Environmental checklists for kidney care

The EDTNA/ERCA is raising awareness among healthcare ~~HC~~ professionals about the environmental impact of kidney replacement therapy. It introduced an environmental checklist as a web-based app,[42] available to help kidney care centres assess their environmental performance and potential areas for improvement.

1.9.3 Carbon calculator for kidney care

A free online carbon footprint calculator has been designed for in-centre HD units, measuring the overall footprint and carbon intensity per patient session while pinpointing greenhouse gas emission hotspots. Developed by the Newcastle renal unit and the Sustainable Healthcare Coalition, and supported by AstraZeneca, it addresses the disproportionate resource use and environmental impacts associated with the treatment of kidney failure and enables other centres to assess their own carbon footprints and target areas for change independently.[43]

1.10 In search of holistic solutions: KitNewCare

Despite the recent progress, a more holistic approach is required to increase the odds of success.

KitNewCare plans to build on previous work and to address and mitigate the environmental impacts of kidney care. Recognizing the need for additional structural changes in various areas, KitNewCare brings together all relevant stakeholders (**table S1**) to facilitate change in the environmental burden of kidney care by redesigning the way kidney care is delivered. KitNewCare will perform an EU-wide mapping of the sustainability of kidney care by a 4-impact factor database ~~LCA~~, that assesses health outcome, environmental impact, social impact, and cost. This EU wide mapping will gather specific data on units of care from all 4 clinical sites, and focus initially on the Peritoneal and Haemodialysis pathways, including all resources used in these areas

These impacts and current knowledge ~~Derived insights hotspots and solution directions~~ will be used to develop sustainable workflow and organisational optimisations using Plan, Do, Study, Act (PDSA) cycles. The project aims to refine and pilot technological innovations in four clinical sites with the support of small and medium-sized enterprises (SMEs) and large industry. To capture the sustainability benefits of prevention of kidney disease (or its progression), exemplar prevention initiatives in European kidney centres will also be analysed. In addition, KitNewcare aims to develop guidelines and recommendations and an actionable dashboard based on the 4-factor ~~LCA~~ model to monitor and benchmark interventions and healthcare centres across the four outcomes. Decision makers and healthcare providers will be informed about KtiNewCare's insights, solutions and policy recommendations. Finally, a Sustainability Network with associated pilot sites will be setup as a public-private partnership for training purposes and upscaling of sustainability solutions beyond the EU-funding period. The entire process will be informed by intensive stakeholder interaction and a Patient and Public Involvement (PPI) programme to ensure proper design, uptake, dissemination and exploitation. KitNewCare's objectives are described in **table 2**.

1.10.1 Improve knowledge

To make an informed decision to improve kidney care pathways, it is essential to encompass social, economic, environmental costs, and assessing the health outcomes of each pathway. Such an approach is crucial for

enhancing the environmental and fiscal sustainability of healthcare ~~HC~~ systems while upholding the delivery of high-quality care.

At present there is no central database which brings together health outcomes and the triple bottom line (environmental, social and financial cost) at hospital department or treatment/pathway level. Current knowledge includes different levels of knowledge on health outcomes, financial, environmental, and social costs. To create a knowledgebase, academic articles published from 2000 onwards will be reviewed to reflect the advancements in both kidney care and public health systems as well the rising costs over the past 25 years.

KitNewCare will identify and synthesise existing data related to health outcomes across the kidney care pathways utilising two approaches. Firstly, conducting both rapid and systematic reviews to identify relevant peer-reviewed and grey literature reporting health outcomes associated with all care pathways. Search strategies will be developed and refined with input from information specialists, health economists and clinicians. The completeness of reporting and quality of identified studies will be assessed using the 24-item Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist[44]. Secondly, extracting relevant data documented by regional and national registries across numerous European countries. These datasets are collectively contributed to the Annual Report of the Registry of ERA.[45] A partner EU-funded project, PREVENTCKD, has been identified that is already collecting additional information on grey literature in diverse European languages regarding the epidemiology of CKD (https://ekha.eu/preventing-ckd/). These treatment outcomes will be collected and published alongside the information collected from the LCA costs

1.10.1.1 Financial costs

Financial costs associated with each care pathway will be estimated based on vectors of unit costs and the volumes of utilisation. The financial costs research be conducted at the 4 sites where solutions/innovations will subsequently be piloted. A database of unit costs will be developed at all participating clinical sites, utilising administrative data in the first instance. Where unit costs are not available, these will be estimated using both top-down (e.g. the cost of in hospital dialysis) and bottom-up (using product costs, resources etc) approaches.

1.10.1.2 Environmental costs

Environmental research will be focused on specific LCA elements relating the entire kidney care pathway. LCA is the primary method for assessing the environmental impacts of products or processes. The process of conducting an LCA starts with delineating the objectives and boundaries of the system under examination, which typically encompasses all stages of a product's life cycle, from raw material extraction to disposal, either

as waste or recycling (**figure 4**). This full life cycle approach is a key difference with usual estimates of environmental impact and provides a more holistic approach to the issue. Subsequently, a comprehensive inventory of material and energy inputs and outputs is compiled, which is then transformed into environmental impacts using characterization factors.[46]

1.10.1.3 Social costs

KitNewCare will analyse two types of social costs. The first point concerns the societal impacts of the manufactured products, such as dialysis solutions, plastic tubing, and disposal bags. ~~The first pertains to the societal implications of the products being manufactured.~~ For instance, various countries have distinct laws concerning occupational safety, child labour regulations, and accident rates, some more robust than others. KitNewCare will evaluate these social costs using Soca V2, which integrates PSILCA (a novel database for social LCA developed by GreenDelta). PSILCA encompasses extensive generic inventory data for nearly 15,000 industry sectors and commodities, facilitating the calculation and evaluation of social impacts throughout product life cycles and the identification of social hotspots.[47,48]

The second type of social costs relates to the societal outcomes of the patient pathways being considered. These will be determined using patient and public involvement e.g. using questionnaires and focus groups across the four clinical centres.

1.10.2 Improve solutions

1.10.2.1 Improve solutions through a quality improvement (QI) approach

Innovation and implementation of pathway/process/workflow improvements, and adoption of new technologies, can be supported by systematic improvement methodologies which are already applied to other challenges in complex healthcare ~~HC~~ systems. These include stakeholder engagement, organisational capability building, collaborative process redesign and PDSA cycles, combining these established approaches with a comprehensive framework for evaluating healthcare systems and interventions.[49]

KitNewCare will co-develop and pilot optimised workflow processes and organisational transformations in 4 different clinical sites in 4 European countries using PDSA improvement cycles on identified hotspots and best practices.

1.10.2.2 Improve solutions through a technological innovation approach

Numerous encouraging case studies exist regarding interventions that effectively decrease environmental impact of kidney care.[50] These include advancements in water treatment, such as re-use of reverse osmosis reject water for alternative purposes, optimising the conversion rate of osmosis units, incorporating forward osmosis for the production of dialysate, the reuse of spent dialysate e.g. as a fertiliser or irrigation for agriculture and regeneration of spent dialysate using adsorption systems (applied in portable dialysis devices that are currently in development), forward osmosis or distillation.[51,52,53,54,55] Advancements in waste reduction include use of centralized acid concentrate distribution systems in the dialysis centre, reuse of dialyzers and production of dialysate from tap water at home (for either HD or PD)[56,57,58,59,60], advancements aimed at decreasing energy consumption encompass heat exchangers utilizing the heat from outgoing dialysate to warm incoming dialysate or utilizing the machine's heat for dialysate warming and use of urea, a by-product, either directly as fuel or as a source of hydrogen.[61]

However, up to this point, there has been no systematic testing of multiple interventions at a single site, nor a deliberate comparison and validation of these applications across various sites or in terms of environmental, social, clinical, and cost-related outcomes. Consequently, it remains uncertain which interventions are most effective.

KitNewCare will co-develop and pilot technological innovations working with industries and kidney care providers in 4 different clinical sites. KitNewCare will collaborate with industrial and academic partners and end-users to collectively identify, prioritize, select, integrate, and pilot technologies in a co-designed process. An established 'innovation challenge methodology' will be used to guide this process. This innovation challenge methodology has proven highly effective in promoting technical innovation within healthcare settings. Notable examples include World's Greenest healthcare ~~HC~~ 2030 and the Nordic White Paper on Sustainable healthcare ~~HC~~.[62] The project will test and benchmark the selected innovations in the 4 clinical sites. The impacts of the new technologies on health outcomes will be assessed as well as environmental and social impacts and costs. In this way, KitNewCare aims to provide transferable solutions and tools that may serve as stepping stones for broader, system-wide transformations.

1.10.2.3 Improve solutions through the development of the benchmarking tool

There is currently no established practice for systematically gathering and evaluating data on the environmental and social impact of hospitals, departments, and other healthcare ~~HC~~ services in Europe.

The Eyefficiency pathway tool estimates the financial and environmental impact and productivity of cataract surgery. However, it does not integrate health outcomes or any other social impacts beyond productivity.[63]

KitNewCare will co-develop and maintain a 4-factor LCA database with social, environmental, health, and financial impacts of kidney care sustainability hotspots. The database will feed into the development of a KitNewCare 4-factor benchmarking dashboard, an online tool which will measure the environmental, social and financial impacts and health outcomes of kidney care centres and their different treatment options, thus empowering them to reduce greenhouse gas emissions, pollution and other environmental impacts and cost, and add social value while maintaining or improving health outcomes.[64]

Once finalized, the tool will allow kidney care centres to monitor and benchmark their impacts over time against other renal centres of similar size and service offer, against centres in their own country or across Europe or against best practice. It will help centres to identify their own environmental and social hotspots and suggest solutions how to address them. Moreover, the information provided by the benchmarking tool will help healthcare organisations and policy makers at national and European level to shift kidney care and other health and care services to more sustainable practices. Without such a tool, sustainability solutions and recommendations are not likely to be implemented and EU-Green Deal objectives in the sustainable healthcare will be difficult.

1.10.3 Improve implementation and upscaling

KitNewCare will combine results into an EU-wide Sustainability Network for continued monitoring, benchmarking, piloting, upscaling and implementing of sustainability solutions and training of healthcare professionals, patients, industry as well as healthcare managers and policy makers.

KitNewCare will embark on the development, delivery, and evaluation of online sustainable kidney care training packages as well as best practice guidance in four languages (English, Spanish, Polish and Italian) drawing from the cutting-edge Sustainable Kidney Care online training modules crafted by the CSH in English. Through this initiative, the programme aims to enhance the capacity of kidney care staff in pilot sites to discern operational changes necessary to tackle unsustainable elements of care. The targeted staff groups for training encompass nephrologists, technologists, kidney pharmacists, kidney dieticians, and dialysis nurses. These resources will be structured as Continuing Professional Development for established and qualified healthcare practitioners. Educational materials will be made available on an open access online learning platform

meticulously designed to facilitate guided self-study, rooted in established theoretical frameworks of effective professional education.

An integrated Dissemination, Exploitation and Communication strategy will maximise impacts in terms of outreach and engagement to support replication, upscaling and uptake. Considering all actors in the kidney care ecosystem and in line with the value proposition analysis of each result, stakeholders will be segmented according to the 'stake' in the project and its outcomes and classified according to two key variables: interest and impact to determine the most appropriate outreach and engagement strategy. A multi-layered approach is pivotal for awareness raising and upscaling at both European level (via online channels, campaigns, media relations and cooperation with European and international associations representing the different target groups) and local level with the support of each partner acting as country representative to liaise with local communities and kidney care ecosystem actors. By intensive stakeholder and end-user involvement in each phase of the project, it will be possible to deliver information that is relevant and usable for external stakeholders and co-develop actionable knowledge translated into multiple communication and educational resources.

1.11 Conclusion

Following its foundational statement, KitNewCare proposes kidney care as a demonstrator and catalyst for developing and testing sustainable healthcare ~~HC~~ tools, solutions, guidelines, and recommendations. Kidney care, with its considerable disease burden, substantial sustainability footprint, and a clearly defined ecosystem, offers a highly suitable use case. Implementing CKD prevention strategies on top of screening campaigns that allow early diagnosis and treatment of CKD, and transplantation would represent the optimal approach to decrease the need for KRT and its environmental impact.[65] However, once KRT is needed, improving knowledge on sustainability, solutions and upscaling and implementing these solutions are essential to improve the sustainability of KRT.

Moreover, tackling numerous hotspots in kidney care, such as high-water usage, energy consumption, plastic use, and waste production/management, will generate solutions that can be applied to other health disciplines. By the project's conclusion, KitNewCare aims to provide a set of common methodologies and solutions,

validated both technically and by end-users across four clinical sites, together with a model for driving implementation at a larger scale.

1.12 Declarations

1.12.1 Ethical approval: It does not apply to the present manuscript

1.12.2 Informed consent to participate. It does not apply to the present manuscript

1.12.3 Competing interests

Alberto Ortiz has received grants from Sanofi and consultancy or speaker fees or travel support from Adviccene, Alexion, Astellas, Astrazeneca, Amicus, Amgen, Boehringer Ingelheim, Fresenius Medical Care, GSK, Bayer, Sanofi-Genzyme, Menarini, Mundipharma, Kyowa Kirin, Lilly, Freeline, Idorsia, Chiesi, Otsuka, Novo-Nordisk, Sysmex and Vifor Fresenius Medical Care Renal Pharma and Spafarma and is Director of the Catedra UAM-Astrazeneca of chronic kidney disease and electrolytes. He has stock in Telara Farma. AO research is also funded by Instituto de Salud Carlos III (ISCIII) FIS/Fondos FEDER RICORS program to RICORS2040 (RD21/0005/0001) funded by European Union – NextGenerationEU, Mecanismo para la Recuperación y la Resiliencia (MRR), COST Action PERMEDIK CA21165, supported by COST (European Cooperation in Science and Technology); PREVENTCKD Consortium Project ID: 101101220 Programme: EU4H DG/Agency: HADEA.

Raymond Vanholder is advisor to AstraZeneca, Glaxo Smith Kline, Fresenius Kabi, Novartis, Kibow, Baxter, Nipro, Fresenius Medical Care and Nextkidney.

Gabriele Donati has received consultancy fees from Medtronic, speaker fees from Mozarc Medical, Fresenius Medical Care, BBraun. He also received grants from Nipro and Alexion.

Karin Gerristen has received consultancy fees from Nextkidney. KG has received funding from the Dutch Growth Fund program NXTGEN HIGHTECH

Mary Lou Wratten is a full-time employee of Mozarc Medical/Bellco.

Brett Duane has received consultancy or speaker fees from Proctor and Gamble, Tepe, private dental clinics, as well as other dental companies.

There are no other competing interests.

1.12.4 Data availability statement: Will be available as Kitnewcare develops

1.12.5 Funding acknowledgement: KitNewCare, Project ID: 101137054, Call: HORIZON-HLTH-2023-CARE-04, Programme: HORIZON. DG/Agency: HADEA. It will cooperate with PREVENTCKD Consortium Project ID: 101101220 Programme: EU4H DG/Agency: HADEA

Figure legends

Figure 1: Natural history of chronic kidney disease and potential for intervention

Figure 2. Prevalence of the different CKD categories presented in the KDIGO risk heatmap.

Figure 3. Years of life expectancy lost in European women on kidney replacement therapy as compared to the general population. Data from ERA[9]

Figure 4. Life cycle assessment (LCA) paradigm for assessing environmental impact.

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1.13 References:

1 Ortiz A; Asociación Información Enfermedades Renales Genéticas (AIRG-E), European Kidney Patients' Federation (EKPF), Federación Nacional de Asociaciones para la Lucha Contra las Enfermedades del Riñón (ALCER), Fundación Renal Íñigo Álvarez de Toledo (FRIAT), Red de Investigación Renal (REDINREN), Resultados en Salud 2040 (RICORS2040), Sociedad Española de Nefrología (SENEFRO) Council, Sociedad Española de Trasplante (SET) Council, Organización Nacional de Trasplantes (ONT). (2021) RICORS 2040: the need for collaborative research in chronic kidney disease. Clin Kidney J. 15(3):372-387. https://doi.org/10.1093/ckj/sfab170

2 Foreman KJ, Marquez N, Dolgert A, Fukutaki K, Fullman N, McGaughey M, Pletcher MA, Smith AE, Tang K, Yuan CW, Brown JC, Friedman J, He J, Heuton KR, Holmberg M, Patel DJ, Reidy P, Carter A, Cercy K, Chapin A, Douwes-Schultz D, Frank T, Goettsch F, Liu PY, Nandakumar V, Reitsma MB, Reuter V, Sadat N, Sorensen RJD, Srinivasan V, Updike RL, York H, Lopez AD, Lozano R, Lim SS, Mokdad AH, Vollset SE, Murray CJL. (2018) Forecasting life expectancy, years of life lost, and all-cause and cause-specific mortality for 250 causes of death: reference and alternative scenarios for 2016-40 for 195 countries and territories. Lancet. 392(10159):2052-2090 https://doi.org/10.1016/S0140-6736(18)31694-5

3 Jager KJ, Kovesdy C, Langham R, Rosenberg M, Jha V, Zoccali C. (2019) A single number for advocacy and communication-worldwide more than 850 million individuals have kidney diseases. Nephrol Dial Transplant. 1;34(11):1803-1805 https://doi.org/10.1093/ndt/gfz174

4 Kovesdy CP. (2022) Epidemiology of chronic kidney disease: an update 2022. Kidney Int Suppl. 12(1):7-11. https://doi.org/10.1016/j.kisu.2021.11.003

5 GBD Chronic Kidney Disease Collaboration. Global, regional, and national burden of chronic kidney disease, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017(2020). Lancet. 395(10225):709-733. https://doi.org/10.1016/S0140-6736(20)30045-3

6 Van der Tol A, Stel VS, Jager KJ, Lameire N, Morton RL, Van Biesen W, Vanholder R. (2020) A call for harmonization of European kidney care: dialysis reimbursement and distribution of kidney replacement therapies. Nephrol Dial Transplant. 1;35(6):979-986. https://doi.org/10.1093/ndt/gfaa035

7 Carriazo S, Aparicio-Madre MI, Tornero-Molina F, Fernández-Lucas M, Paraiso-Cuevas V, González-Parra E, Del Río-Gallegos F, Marques-Vidas M, Alcázar-Arroyo R, Martins-Muñoz J, Sánchez-Villanueva R, Gil-Casares B, Gutiérrez-Martínez E, Martínez-Rubio MP, Ortiz A; (2022) REMER Committee. Impact of different COVID-19 waves on kidney replacement therapy epidemiology and mortality: REMER 2020. Nephrol Dial Transplant. 19;37(11):2253-2263. https://doi.org/10.1093/ndt/gfac234

8 Pippias M, Stel VS, Abad Diez JM, Afentakis N, Herrero-Calvo JA, Arias M, Tomilina N, Bouzas Caamaño E, Buturovic-Ponikvar J, Čala S, Caskey FJ, Castro de la Nuez P, Cernevskis H, Collart F, Alonso de la Torre R, García Bazaga Mde L, De Meester J, Díaz JM, Djukanovic L, Ferrer Alamar M, Finne P, Garneata L, Golan E, González Fernández R, Gutiérrez Avila G, Heaf J, Hoitsma A, Kantaria N, Kolesnyk M, Kramar R, Kramer A, Lassalle M, Leivestad T, Lopot F, Macário F, Magaz A, Martín-Escobar E, Metcalfe W, Noordzij M, Palsson R, Pechter Ü, Prütz KG, Ratkovic M, Resić H, Rutkowski B, Santiuste de Pablos C, Spustová V, Süleymanlar G, Van Stralen K, Thereska N, Wanner C, Jager KJ. (2015) Renal replacement therapy in Europe: a summary of the 2012 ERA-EDTA Registry Annual Report. Clin Kidney J. 8(3):248-61. https://doi.org/10.1093/ckj/sfv014

9 Boerstra B, Boenink R, Astley M, Bonthuis , ElHafeez S, Monzon F, Asberg A, Beckerman P, Bell S, Amenos A, de la Nuez P, ten Dam M, Debska-Slizien A, Gjorgjievski, N, Giudotti R, Helve J, Hommel K, Idrizi A, Indrioason O, Kramer A. (2024). The ERA Registry Annual Report 2021: a summary. Clinical kidney journal, 17(2). https://doi.org/10.1093/ckj/sfad281

10 Webster AC, Nagler EV, Morton RL, Masson P. (2017) Chronic Kidney Disease. Lancet. 25;389(10075):1238-1252. https://doi.org/10.1016/S0140-6736(16)32064-5

11 Sustainable Healthcare. Resources. https://sustainablehealthcare.org.uk/resources Accessed March 21st 2024

12 Carriazo S, Villalvazo P, Ortiz A. (2021) More on the invisibility of chronic kidney disease… and counting. Clin Kidney J. 15(3):388-392. https://doi.org/10.1093/ckj/sfab240

13 Alfano G, Perrone R, Fontana F, Ligabue G, Giovanella S, Ferrari A, Gregorini M, Cappelli G, Magistroni R, Donati G. (2022) Rethinking Chronic Kidney Disease in the Aging Population. Life (Basel). 12(11):1724. https://doi.org/10.3390/life12111724

14 Ruiz-Ortega M, Rayego-Mateos S, Lamas S, Ortiz A, Rodrigues-Diez RR. (2020) Targeting the progression of chronic kidney disease. Nat Rev Nephrol. 16(5):269-288. https://doi.org/10.1038/s41581-019-0248-y

15 Cordero L, Ortiz A. (2024) Decreased life expectancy: a health outcome not corrected by kidney replacement therapy that emphasizes the need for primary prevention of CKD. Clin Kidney J. 17(5) https://doi.org/10.1093/ckj/sfae053

16 Perez-Gomez MV, Bartsch LA, Castillo-Rodriguez E, Fernandez-Prado R, Fernandez-Fernandez B, Martin-Cleary C, Gracia-Iguacel C, Ortiz A. (2019) Clarifying the concept of chronic kidney disease for non-nephrologists. Clin Kidney J. 12(2):258-261. https://doi.org/10.1093/ckj/sfz007

17 KDIGO 2024 Clinical Practice Guideline for the Evaluation and Management of CKD. (2024) Kidney Int;105(4S),S117–S314.

~~18 Cordero L, Ortiz A. (2024) Decreased life expectancy: a health outcome not corrected by kidney replacement therapy that emphasizes the need for primary prevention of CKD. Clin Kidney J. 17(5) https://doi.org/10.1093/ckj/sfae053~~

19 Lenzen M, Malik A, Li M, Fry J, Weisz H, Pichler PP, Chaves LSM, Capon A, Pencheon D. (2020) The environmental footprint of health care: a global assessment. Lancet Planet Health. 4(7):e271-e279. https://doi.org/10.1016/S2542-5196(20)30121-2\

20 Vanholder R, Conway PT, Gallego D, Scheres E, Wieringa F. (2023) The European Kidney Health Alliance (EKHA) and the Decade of the KidneyTM. Nephrol Dial Transplant. 38(5):1113-1122. https://doi.org/10.1093/ndt/gfac211

21 Wieringa F, Søndergaard H, Ortiz A. (2023) Coordinating efforts to optimize next-generation kidney replacement therapies: the European Kidney Health Alliance Work Group 'Breakthrough Innovation'. Clin Kidney J. 16(6):885-890. https://doi.org/10.1093/ckj/sfad016

22 GBD 2019 Risk Factors Collaborators. (2020) Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet. 396(10258):1223-1249. https://doi.org/10.1016/S0140-6736(20)30752-2

23 Net Zero Carbon Healthcare guide. https://www.arup.com/-/media/arup/files/publications/n/net-zero-carbon-HC-guide.pdf Accessed January 15th 2024

24 Faculty Interest Group Sustainable Development of Public Health Special. The NHS: Carbon Footprint. https://www.fph.org.uk/media/3126/k9-fph-sig-nhs-carbon-footprint-final.pdf Accessed January 15th 2024

25 OECD. Health in the 21st Century. Putting Data to Work for Stronger Health Systems https://www.oecd.org/publications/health-in-the-21st-century-e3b23f8e-en.htm Accessed January 15th 2024

26 Sustainable HC. Cumulative Savings from Green Nephrology Innovations - poster presented at RA-BTS Congress 201. https://sustainableHC.org.uk/file/295/download?token=ljhRclNx Accessed January 15th 2024

27 Connor A, Lillywhite R, Cooke MW. (2011) The carbon footprints of home and in-center maintenance hemodialysis in the United Kingdom. Hemodial Int. 15(1):39-51 https://doi.org/10.1111/j.1542-4758.2010.00523.x

28 Lim AE, Perkins A, Agar JW. (2013) The carbon footprint of an Australian satellite haemodialysis unit. Aust Health Rev. 37(3):369-374. https://doi.org/10.1071/AH13022

29 Ben Hmida M, Mechichi T, Piccoli GB, Ksibi M. (2023) Water implications in dialysis therapy, threats and opportunities to reduce water consumption: a call for the planet. Kidney Int. 104(1):46-52. https://doi.org/10.1016/j.kint.2023.04.008.

30 Molano-Triviño A, Wancjer B, Neri MM, Karopadi AN, Rosner M, Ronco C. (2018) Blue Planet dialysis: novel water-sparing strategies for reducing dialysate flow. Int J Artif Organs. 41(1):3-10. https://doi.org/10.5301/ijao.5000660

31 Vanholder R, Agar J, Braks M, Gallego D, Gerritsen KGF, Harber M, Noruisiene E, Pancirova J, Piccoli GB, Stamatialis D, Wieringa F. (2023) The European Green Deal and nephrology: a call for action by the European Kidney Health Alliance. Nephrol Dial Transplant. 4;38(5):1080-1088. https://doi.org/10.1093/ndt/gfac160.

32 Bhutta MF. (2008) Fair and ethical trade in health procurement. Lancet. 6;372(9654):1935-7. https://doi.org/10.1016/S0140-6736(08)61826-7.

33 Norton JM, Grunwald L, Banaag A, Olsen C, Narva AS, Marks E, Koehlmoos TP. (2021) Racial and Socioeconomic Disparities in CKD in the Context of Universal Health Care Provided by the Military Health System. Kidney Med. 4(1):100381. https://doi.org/10.1016/j.xkme.2021.08.015.

34 van Manen JG, Korevaar JC, Dekker FW, Reuselaars MC, Boeschoten EW, Krediet RT (2001) NECOSAD Study Group. Netherlands Cooperative Study on Adequacy of Dialysis. Changes in employment status in end-stage renal disease patients during their first year of dialysis. Perit Dial Int. 21(6):595-601.

35 Healthcare Without Harm. Global Green and Healthy Hospitals' Climate Impact Check-up Tool. https://greenhospitals.org/checkup Accessed March 21st 2024

36 HEAL. https://www.env-health.org/issues/health-diseases. Accessed March 21st 2024

37 Sustainable healthcare. https://sustainablehealthcare.org.uk. Accessed March 21st 2014

38 Stigant CE, Barraclough KA, Harber M, Kanagasundaram NS, Malik C, Jha V, Vanholder RC (2023) Our Shared Responsibility – The Urgent Necessity of Global Environmentally Sustainable Kidney Care, Kidney International https://doi.org/10.1016/j.kint.2022.12.015

39 ERA Sustainable Nephrology Task Force initiative. https://www.era-online.org/publications/sustainable-nephrology-task-force/#:~:text=The%20main%20purpose%20of%20the,term%20to%20achieve%20specific%20tasks Accessed March 21st 2024

40 Piccoli GB, Cupisti A, Aucella F, Regolisti G, Lomonte C, Ferraresi M, Claudia D, Ferraresi C, Russo R, La Milia V, Covella B, Rossi L, Chatrenet A, Cabiddu G, Brunori G (2020) On the Behalf of Conservative treatment, Physical activity and Peritoneal dialysis project groups of the Italian Society of Nephrology. Green nephrology and eco-dialysis: a position statement by the Italian Society of Nephrology. J Nephrol. 33(4):681-698. https://doi.org/10.1007/s40620-020-00734-z

41 Alfano G, Bergesio F, Lombardi M, Piccoli GB, Salomone M, Bonucchi D, Cusinato S, Colturi C, Quintaliani P, Santoro A, D'Alessandro C, Ciciani AM (2024) Project Group on Green Nephrology of the Italian Society of Nephrology. Eco-dialysis in Italy: where are we? National survey on the eco-sustainability of dialysis across Italian dialysis centers. J Nephrol. https://doi.org/10.1007/s40620-023-01882-8

42 EDTNAERCA. Environmental checklist. https://www.edtnaerca.org/environmental-checklist. Accessed March 21st 2024

43 UK Kidney. Sustainable kidney care committee. https://ukkidney.org/sustainable-kidney-care-committee. Accessed March 21st 2024

44 Husereau D, Drummond M, Augustovski F, de Bekker-Grob E, Briggs AH, Carswell C, Caulley L, Chaiyakunapruk N, Greenberg D, Loder E, Mauskopf J, Mullins CD, Petrou S, Pwu RF, Staniszewska S; (2022) CHEERS 2022 ISPOR Good Research Practices Task Force. Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) Statement: Updated Reporting Guidance for Health Economic Evaluations. https://doi.org/10.1111/1471-0528.17012

45 European Renal Association. ERA Registry Annual Report. 2020. https://www.era-online.org/wp-content/uploads/2022/12/ERA-Registry-Annual-Report2020.pdf. Accessed 14th March 2024

46 ISO standards 14040. https://www.iso.org/standard/37456.html.Accessed 14th March 2024

47 Soca v2. Available at https://www.openlca.org/soca-v2-new-version. Accessed 14th March 2024

48 PSILCA. https://psilca.net. Accessed 14th March 2024

49 Ogrinc G, Dolansky M, Berman AJ, Chambers DA, Davies L. (2021) Different approaches to making and testing change in HC. BMJ. 17;374:n1010. http://doi.org/10.1136/bmj.n1010

50 Centre for Sustainable HC. Resources. https://sustainablehealthcare.org.uk/resources.

Accessed 14th March 2024

51 Agar JW, Simmonds RE, Knight R, Somerville CA. Using water wisely: New, affordable, and essential water conservation practices for facility and home hemodialysis. Hemodial Int. 2009 Jan;13(1):32-7. https://doi.org/10.1111/j.1542-4758.2009.00332.x

52 Next Kidney. https://nextkidney.com/ Accessed 14th March 2024

53 Mauerer M, Rocksch T, Dannehl D, Schuch I, Mewis I, Förster N, Ulrichs C, Schmidt U. (2023) Replacing Mineral Fertilizer with Nitrified Human Urine in Hydroponic Lettuce (Lactuca sativa L.) Production. Sustainability. 15:10684. Available from: https://doi.org/10.3390/su151310684.

54 Filtration Separation. Aquaporin membranes cut hemodialysis water costs. https://www.filtsep.com/content/news/aquaporin-membranes-cut-hemodialysis-water-costs.

Accessed 14th March 2024

55 Dou P, Donato D, Guo H, Zhao S, He T. (2020) Recycling water from spent dialysate by osmotic dilution: Impact of urea rejection of forward osmosis membrane on hemodialysis duration. Desalination. 15; 496:114605. https://doi.org/10.1016/j.desal.2020.114605

56 ERA. Towards Green Practice. Good Practice guide. https://www.era-online.org/wp-content/uploads/2023/09/SFNDT_EN_guide-complet_VF_HD.pdf

Accessed 14th March 2024

57 Duygan B, Udert K, Remmele A, and McArdell C. (2021) Removal of pharmaceuticals from human urine during storage, aerobic biological treatment, and activated carbon adsorption to produce a safe fertilizer Resources, Conservation and Recycling 166:105341. doi: https://doi.org/10.1016/j.resconrec.2020.105341.

58 Bradford Teaching Hospitals NHS Foundation Trust. Centralized distribution of acid for hemodialysis. Mapping Greener HC. 2011. https://map.sustainableHC.org.uk/bradford-teaching-hospitals-nhs-foundation-trust/central-delivery-acid-haemodialysis

59 Basile C, Davenport A, Mitra S, Pal A, Stamatialis D, Chrysochou C, Kirmizis D. (2021) Frontiers in hemodialysis: Innovations and technological advances. Artif Organs. 45(2):175-182. https://doi.org/10.1111/aor.13798.

60 Central Delivery of Acid for Haemodialysis. Available at https://networks.sustainablehealthcare.org.uk/resources/central-delivery-acid-haemodialysis. Accessed 14th March 2024

61 Zhu B, Liang Z, and Zou R. (2020) Designing Advanced Catalysts for Energy Conversion Based on Urea Oxidation Reaction. Nano Micro Small. https://doi.org/10.1002/smll.201906133.

62 Green innovation group. Health Use Case for Nordic Innovation https://www.greeninnovationgroup.com/husca. Accessed 14th March 2024

63 Eye efficiency tool. https://eyefficiency.org. Accessed 14th March 2024

64 Thiel C L et al. (2020) Utilizing off-the-shelf LCA methods to develop a 'triple bottom line' auditing tool for global cataract surgical services. https://doi.org/10.1016/j.resconrec.2020.104805.

65 Ortiz A, Quiroga B, Díez J, Escalada San Martín FJ, Ramirez L, Pérez Maraver M, Martínez-Berganza Asensio ML, Arranz Arija JÁ, Alvarez-Ossorio Fernández JL, Córdoba R, Brotons Muntó F, Cancelo Hidalgo

MJ, Carles Reverter J, Plasencia-Rodríguez C, Carretera Gómez J, Guijarro C, Freijo Guerrero MDM, de Sequera P. (2023)The Spanish Scientific Societies before the ESC 2021 guidelines on vascular disease prevention: Generalizing the measurement of albuminuria to identify vascular risk and prevent vascular disease. Nefrologia (Engl Ed). 2023 Mar-Apr;43(2):245-250. https://doi.org/10.1016/j.nefroe.2023.06.005

Comments	**Our response/edit**
COMMENTS FOR THE AUTHOR: Reviewer #1: Thank you to the authors for submitting this manuscript which functions as a commentary/position paper for this new initiative. It is well conceptualised and written. 1) The table numbering needs correction. Table 2 is duplicated as Table 3.	Removed duplicate table! Sorry ☺
2) The figure numbering and inclusion needs correction. Three figures are included but four are listed.	Renamed figures- also sorry!
3) Please also revise the visual abstract to improve its readability and alignment to the template JNeph visual abstract.	Saved as grey version to comply
Reviewer #2: This paper details KitNewCare, an EU-funded project which has the overarching aim of reducing kidney care's environmental, social, and financial impact while optimising health outcomes. It is a project of impressive scale and one that the kidney care community should be aware of. However, I have a number of concerns about the paper, as outlined below.	Thanks
* Overall, I found it quite hard to follow. For instance, it is stated that KitNewCare will undertake a 4-impact factor LCA that assesses health outcome, environmental impact, social impact, and cost. The health outcome, environmental impact, social impact, and cost of what facet of kidney care? All stages? All CKD 5 treatment pathways? Targeted areas? Will the LCAs be undertaken at the 4 sites where solutions will be piloted? '	Changed 4 impact factor LCA to 4 impact factor… Added this sentence to clarify "This EU wide mapping will gather specific data on units of care from all 4 clinical sites, and focus initially on the Peritoneal and Haemodialysis pathways, including all resources used in these areas"
There is also a fair bit of jargon - e.g. there is a line that says Derived insights hotspots and solution directions will be used to develop sustainable workflow and organisational	Changed to "These impacts and current knowledge"

optimisations with Plan, Do, Study, Act (PDSA) cycles'. What are derived insight hotspots?	
And solution directions? I wonder if the paper could be simplified so that its content is more accessible to the average reader.	Removed solutions directions
* In the abstract, HD and its impact are specifically mentioned. Reference should be made to PD as well	In addition to energy, haemodialysis and peritoneal dialysis require transportation of patients and personnel to and from facilities,
I found the 'Who are KitNewCare' section confusing. This implies that KitNewCare is/are people rather than an initiative. Do the initials belong to people involved in or driving KitNewCare?	Changed to What is Kitnewcare?
There are also lots of other abbreviations in this section that need to be written in full at first mention to make them understandable (e.g. ICONS, 040, TEM, TCD, as well as the organisations - EDTNA/ERCA, EKHA, EKPF).	Checked these: TCD- first mentioned page 7 and was written in full, European Dialysis Transplant Nurse Association/ European Renal Care Association (EDTNA/ERCA)- first mentioned page 7 and was written in full, , EKHA- first mentioned page 7 and was written in full, EKPF- first mentioned page 7 and was written in full, Stiftelsen TEM (TEM)- added ICONS = is not an acronym, its just an organisation written in capitals 040= is also not an acronym
The section titled 'The healthcare burden of CKD' is repetitive in parts. Could this be edited/tightened up?	We concur with the referee and apologize. This has now been corrected
* In the Environmental impact of KRT section, the first paragraph discusses the carbon footprint of 'dialysis' then emissions estimates are presented. It needs to be made clear that these estimates refer to HD, not dialysis generally.	This has been made clear as suggested
* In this same section, there is discussion	We thank the reviewer for the suggestion. Done as suggested

about the fact that PD likely has an overall environmental impact similar to haemodialysis. The authors should look at a recently published paper (McAlister et al, JASN 2024) that quantifies PD's carbon impact and consider revising this paragraph accordingly.	
* In the health outcomes section, the paper talks of rapid and systematic reviews and looking at registry data. Is this separate to the LCA or will the information obtained inform the LCA? If separate to the LCA, what will be the data be used for - ie what actions will follow from it?	These treatment outcomes will be collected and published alongside the information collected from the LCA costs
* What is meant by 'Financial costs associated with each care pathway will be estimated based on vectors of unit costs and the volumes of utilisation'? Will the financial costs research be conducted at the 4 sites where solutions/innovations will subsequently be piloted?	Good point of clarification- added this "Financial costs associated with each care pathway will be estimated based on vectors of unit costs and the volumes of utilisation. The financial costs research be conducted at the 4 sites where solutions/innovations will subsequently be piloted. "
The environmental costs section states that environmental research will be focused on specific LCA elements relating the entire kidney care pathway. What specific LCA elements? Again, I don't understand what is to be done here. Also, this section details what an LCA is. Why is this information included here when we are told earlier that LCAs will focus not just on environmental factors but also health outcomes, cost, social factors etc.	I agree this is somewhat confusing- LCA can include social and financial and environmental- but not health outcome – So I have changed some of the wording including "There is a need to improve knowledge around the environmental and financial cost of kidney care and social and health outcomes of each patient pathway including using holistic tools such as life cycle assessment (LCA)." I have also changed 4 factor LCA- to simply 4 factor to clarify this point throughout the document.
* With the social costs, which manufactured products will be considered? Those used for dialysis? Or other parts of kidney care?	Added this ". The first point concerns the societal impacts of the manufactured products, such as dialysis solutions, plastic tubing, and disposal bags"

Section 6: Declaration of agreement. *All* authors, unchanged, new and removed *must* sign this declaration.

(NB: Please print the form, sign and return a scanned copy. Please note that signatures that have been inserted as an image file are acceptable as long as it is handwritten. Typed names in the signature box are unacceptable.)

	First name	Family name		Signature	Affiliated institute	Date
1st Author	**Brett**	**Duane**	I agree to the proposed new authorship shown in section 4		**TCD**	**17.05.2024**
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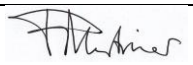
8th Author	**Frances**	**Mortimer**	I agree to the proposed new authorship shown in section 4		**Centre for Sustainable Healthcare**	**23/05/2024**
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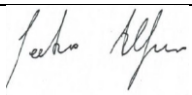
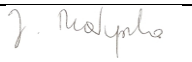
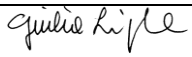
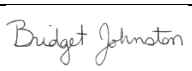
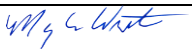
12th Author	**Gaetano**	**Alfano**	I agree to the proposed new authorship shown in section 4		**University Hospital of Modena, Nephrology Unit**	**17May2024**
13th Author	**Jolanta**	**Malyszko**	I agree to the proposed new authorship shown in section 4		**Department of Nephrology, Dialysis and Internal Medicine, Warsaw Medical University, Poland**	**20/5/2024**
14th Author	**Giulia**	**Ligabue**	I agree to the proposed new authorship shown in section 4		**Dip. CHIMOMO, University of Modena and Reggio Emilia**	**17May2024**
15th Author	**Bridget**	**Johnston**	I agree to the proposed new authorship shown in section 4		**Trinity College Dublin, School of Medicine**	**29May2024**
16th Author	**Mary Lou**	**Wratten**	I agree to the proposed new authorship shown in section 4		**Bellco/Mozarc Medical**	**23May2024**
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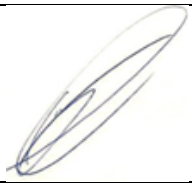
19th Author	**Alberto**	**Ortiz**	I agree to the proposed new authorship shown in section 4		**IIS-Fundacion Jimenez Diaz UAM**	**23May2024**

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Improving the sustainability and quality of kidney health care through life cycle assessments, quality improvement, education and technical innovations: the KitNewCare approach

Duane et al. Trinity College Dublin

Background

Kidney disease's escalating burden and costly treatments, like haemodialysis and peritoneal dialysis, underscore a pressing need for sustainable kidney care. The current approach lacks environmental sustainability, contributing to resource depletion and high healthcare costs. Addressing sustainability in kidney care is imperative for mitigating environmental impact and ensuring long-term viability.

Methods

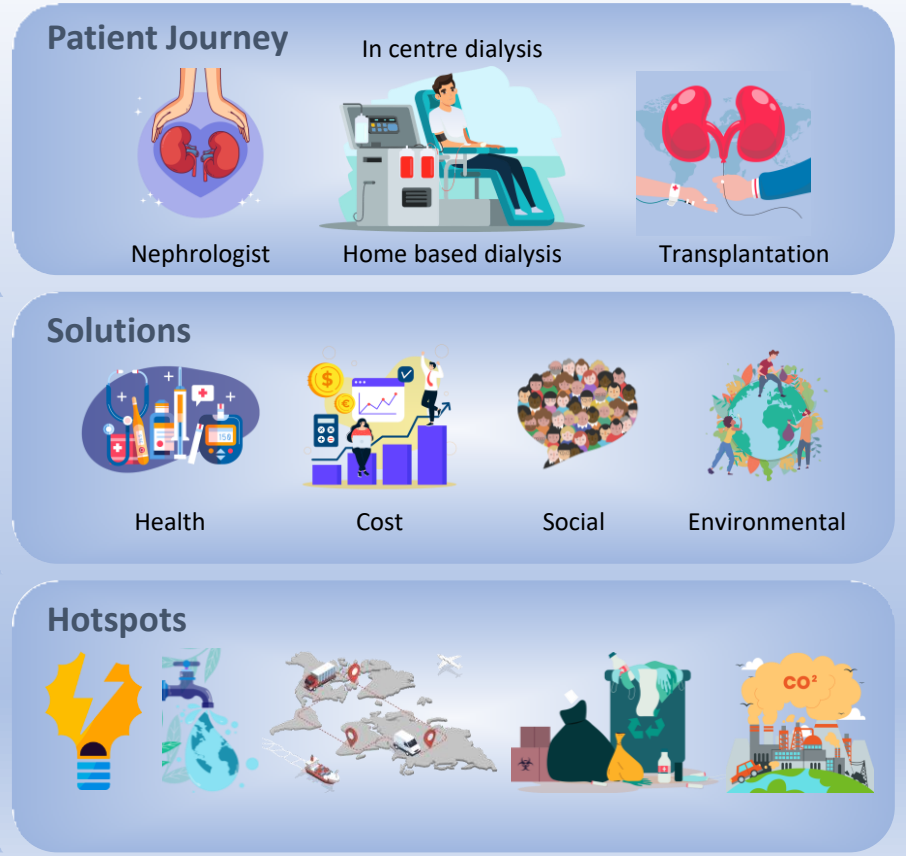
KitNewCare employs diverse methods to enhance kidney care sustainability, including life cycle assessments, quality improvement initiatives, educational programs, and technological innovations. By integrating these approaches, the project aims to reduce the environmental, social, and financial impacts of kidney care while optimizing health outcomes. Through collaboration with healthcare professionals and industry partners, KitNewCare seeks to develop and implement sustainable practices across the kidney care continuum, ultimately fostering a more resilient and eco-friendly healthcare system.

Results: main table

Improve implementation and upscaling **(WP5,WP6)**

Improve solutions **(WP3, WP4)**

Improve knowledge **(WP2)** and awareness **(WP6)**



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Conclusions

KitNewCare endeavours to revolutionize kidney care with sustainable practices and innovative solutions, maintaining health outcomes through collaborative interdisciplinary efforts.