Institution: University of East London (UEL)		
Unit of Assessment: 11 Computer Science and Informatics		
Title of case study: Who pays for that post? Upgrading data centres energy efficiency		
Period when the underpinning research was undertaken: 2013 – 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Dr Rabih Bashroush	**Role(s) (e.g. job title):** Reader in Distributed Systems and Software Engineering	**Period(s) employed by submitting HEI:** 2010 - present
Period when the claimed impact occurred: 2014 – 2020 (ongoing)		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact (indicative maximum 100 words)

As the demand for digital services rise, the environmental burden of the digital infrastructure is evident. Dr Bashroush's research outlines how data centres can improve to be more energy efficient, mitigating the ecological costs of the cyber-revolution and shedding new light on the energy consumption of digital services.

The impact of the research can be classified under three main areas: energy savings and decreased environmental impact of data centres; increased industry capacity and knowledge transfer of best practices; and change to public policy and international standards.

2. Underpinning research (indicative maximum 500 words)

The energy consumption of the digital infrastructure is staggering; it was estimated that 3% of world electricity is consumed by data centres, while accounting for more greenhouse gas emissions than the entire aviation industry. Continuously connected culture, usually with multiple linked devices, necessitates change in data centre practice to meet demand. Dr Bashroush specialises in improvements in the energy efficiency of data centres and promotes and facilitates the uptake of environmentally sound products and services through mathematical models.

Reducing server overprovisioning

One of the main contributors of energy wastage in data centres is idle power consumption, where servers consume significant amount of electricity while doing no productive work. Organizations frequently struggle to accurately calculate the required number of servers to avoid service disruption during peak demand or due to hardware failure, often deploying many more servers than necessary to run their digital services. Research conducted in collaboration with Microsoft, produced a new modelling technique based on breaking applications into modalities. **(R4)** These modalities are aggregated to approximate the total number of servers needed to run a digital service at a mere 30% overprovisioning level, down from industry average of 300% overprovisioning, thus saving significant amount of energy consumption as well as the excess electrical and cooling infrastructure needed to run the additional servers.

Optimising hardware refresh cycles

Data centres must optimize hardware refresh rates (how often servers are replaced) to balance capacity, efficiency and cost. Dr Bashroush's work on PEDCA **(G1)** and EURECA **(G2)** showed due to ill-planned refresh cycles, that in Europe, 40% of deployed servers consumed 66% of the energy while producing only 7% of the compute capacity. Accordingly, a complete set

of mathematical models were created to help optimise refresh rates, factoring in a wide range of parameters: performance and capacity; use-phase; and embodied environmental impact of servers **(R1)**. To drive the uptake of these practices in industry, economic and financial models were also created based on real-life case studies conducted in multiple countries. **(R3)**

The case for circular economy practices

As Moore's Law aged (the rate of increase in energy efficiency in subsequent processor generations), the case for refresh became more complex. The research produced novel data and mathematical models to show how refurbished servers with the right configuration can present a much better performance and environmental saving opportunities compared to refreshing with new serves. **(R2, G4)**

A new generation of Key Performance Indicators (KPI)

Dr Bashroush identified KPI's that measure and calculate appropriate energy efficiency as a significant area for innovation. He proposed an alternative measure, based on productive output by the servers as the focal indicator of performance. Founded on lessons learned from eBay and other industry projects, the workload driven approach has wide industrial adoption and will see a new International Organization for Standardisation (ISO) directive created for a workload-based KPI for energy efficiency. **(R5, R6, G2)**

3. References to the research (indicative maximum of six references)

R1. R. Bashroush, *A Reasoning Framework For Hardware Refresh in Data Centres*, IEEE Transactions on Sustainable Computing, 2018.
R2. R. Bashroush, N. Rteil, R. Kenny, and A. Wynne, *Optimizing server refresh cycles: The case for circular economy with an aging Moore's Law*, IEEE Transactions on Sustainable Computing, 2020.
R3. J. Doyle and R. Bashroush, *Case Studies for achieving a Return on Investment with a Hardware Refresh in Organizations with Small Data Centers*, IEEE Transactions on Sustainable Computing, 2020.
R4. R. Bashroush and M. Nouriddine, *A Cost Effective Cloud Datacenter Capacity Planning Method Based on Modality Cost Analysis*, International Journal of Communication Networks and Distributed Systems, Volume 11, N3, 2013.
R5. R. Bashroush, E. Woods and A. Noureddine, *Data Center Energy Demand: What Got Us Here Won't Get Us There*, IEEE Software. Volume 33, Issue 2, pages 18-21, 2016.
R6. R. Bashroush and E. Woods, *Architectural Principles for Energy-Aware Internet-Scale Applications*, IEEE Software, Volume 34, Issue: 3, pages 14-17, 2017.

G1. EU FP7 PEDCA, grant number 649972 (July 2013 – Jan 2015), Role: Overall Project Coordinator; Value: €1.8M (UEL share €250K).
G2. EU H2020 EURECA, grant number 320013 (March 2015- March 2018); Role: Overall Project Coordinator; Value: €1.5M (UEL share €414K).
G3. Innovate UK, Knowledge Transfer Partnership – Bamboo Systems, partnership number 12304 (November 2020 – June 2023); Value: £237K.
G4. Innovate UK, Knowledge Transfer Partnership - TechBuyer, partnership number 11485 (July 2019 – June 2021); Value: £180K.
G5. Interxion/Digital Reality, PhD Studentship in Renewable Energy Use in Data Centers, (September 2020 – August 2023); Value: £50k.

4. Details of the impact (indicative maximum 750 words)

By identifying and addressing the energy consumption of processes which many users don't consider, Dr Bashroush's research helps the public to grasp environmental implications by comparing data centre energy uses to figures which can be easily visualised. The comparison of

a single Instagram post by Cristiano Ronaldo to an equivalent energy use of 10 UK households for a year was especially appreciated by the media **(S1).**

Along with the work he conducted under initiatives such as PEDCA **(G1)** and EURECA **(G2)**, the research has mobilised change in organisational interest and uptake of sustainable technologies and practices, while providing key data points and direction that underpin policymaking.

Innovating public policy and standards for industry

Dr Bashroush contributed analysis of the largest dataset ever collected on data centres in Europe, covering over 337 data centres, to advise EU legislation for Servers and Online Storage Devices and served on expert working groups. In the EU Green Public Procurement (GPP) Criteria for Data Centres, Dr Bashroush's research **(R1)** and analysis **(S2)** shaped the scope of the policy and relevant best practices **(S3)**.

In 2017, Bashroush led the committee to make recommendations for policy intervention on cross-border EU Green ICT for 2020-2030 to open standards for reporting data centre energy use. Resulting policy recommendations have seen wider adoptions such as by the USA Federal Spending Bill, December 2020. **(S4)**

Dr Bashroush helped shape policies and research programmes, serving on the expert committees that addressed Green ICT Research and Innovation agenda for the next EU Framework Programme of funding **(S5)** and wrote the Best Environmental Management Practices for the EU Eco-Management and Audit Scheme Sectorial Reference Document of the Telecommunications and ICT Services sector.

Dr Bashroush serves on the HMG Sustainable Technology Advice & Reporting (STAR) cross-government committee where he informs digital strategies, including the uptake of circular economy practices within the government **(R4, S6)**. Dr Bashroush contributed to the All-Party Parliamentary Group on Climate Change work, driving UK data centre sustainability policy.

Policy guidance issued by the Amsterdam Economic Board **(S7)** made major reference to the significance of the research **(R1)**. Other policy influencing appointments include his appointment in 2016 as the coordinator of the EU Commission DG CONNECT Research Cluster encompassing all funded EU projects in the area of Cloud and Data Centre Energy Efficiency, equating to more than £40M of funding.

Standardisation

Dr Bashroush's research on capacity planning **(R4)** and hardware refresh **(R1)** were referenced as best practices in the CLC-TR 50600-99-2:2018 (Information technology - Data centre facilities and infrastructures; Recommended practices for environmental sustainability) standard for reducing hardware deployment and optimising refresh rates in data centres respectively. **(S8)**

Dr Bashroush was nominated by The Green Grid to lead the effort of converting the Data Centre Maturity Model (DCMM) to an international standard. He was subsequently appointed as the editor of the new standard EN50600-5-1 (Information technology – Data Centre facilities and infrastructures – Maturity Model) and led its development. Dr Bashroush continues to serve on advisory committees, shaping standardisation policies.

Energy savings and environmental impact

The research served as the basis of the Microsoft planning tool for the MS Lync Server solution **(R4, S9)**. The tool was widely used by data centres to calculate the number of servers needed to run a specific deployment of the MS Lync solution, now Skype for Business.

Dr Bashroush's work on EURECA, which led to primary energy savings of over 131 GWh/year in data centres across Europe, equated to saving over 27 thousand tons of CO2 emissions. **(S2)**

A number of government projects in Europe used the research to achieve substantial savings by consolidating their infrastructure, including: the UK DEFRA UnITy consolidating data centres from 16 government agencies within one procurement exercise; the Irish Central government project to rationalise 200 facilities; and local government facilities in three counties of Ireland. **(S9)**

Developing workforce capacity to improve energy efficiency

Based on the research conducted under the PEDCA project **(G2)** that identified skill gaps, an energy efficiency best practice training programme was created that was delivered in Germany, the Netherlands and the UK. Overall, more than 300 early career participants working in the technology sector attended the face-to-face training. The UK programme included a data centre boot camp event, which was covered by ITV London and cited in a UK government report as a best practice **(S10).** Shifting focus to senior and managerial level audiences fourteen training events were organised between 2015 and 2018 in ten countries, training over 800 stakeholders. Over 300 data centres were supported in adopting new best practices as a direct result. **(S2)**

5. Sources to corroborate the impact (indicative maximum of 10 references)

S1. https://www.rt.com/sport/506960-cristiano-ronaldo-instagram-energy/

S2a. R. Bashroush, *EURECA Deliverable D5.2: Pilots & Case Studies,* 2018. https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5bb752bc6&appId=PPGMS

S2b. R. Bashroush, *EURECA Final Report,* 2018. https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5bb754090&appId=PPGMS

S3. EU Green Public Procurement (GPP) Criteria for Data Centres, Server Rooms and Cloud Services, 2020. https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/development-eu-green-public-procurement-gpp-criteria-data-centres-server-rooms-and-cloud

S4. Cross-border EU-level Intervention on Green ICT. 2018 (report link at the bottom of the page). https://ec.europa.eu/digital-single-market/en/news/experts-and-stakeholders-advise-cross-border-eu-level-intervention-green-ict

S5. https://ec.europa.eu/digital-single-market/en/news/expert-and-stakeholder-consultation-workshop- research-green-ict-2020-2030

S6. Testimonial of Adam Turner, Chair of STAR Committee, DEFRA.

S7. https://www.amsterdameconomicboard.com/app/uploads/2018/06/Circulaire-Dataservers- Rapport-2018.pdf

S8. The MS Lync Capacity Planning Tool. http://www.microsoft.com/en- us/download/details.aspx?id=12295/

S9.https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/817555/DEFRA_Government_Major_Projects_Portfolio_data_September_2018.csv/preview

S10. PEDCA Training Pilot at UEL. http://datacentreessentials.eu/