Research on Energy Transition, Digitalisation and Cyber security

Dr Olamide Jogunola PhD, MIEEE, FHEA

Lecturer in Cyber Security

Researcher in Cyber Security of Smart Critical Infrastructure, including Energy Network

Department of Computing and Mathematics

Manchester Metropolitan University, UK

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Manchester Metropolitan University

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Next Generation Network

My research in AI, Blockchain & Energy

Peer-to-Peer Energy Trading (£2m)

- Funded by EPSRC UK-S.Korea
- 9 partners
- Imperial college, Oxford uni., …
- Developed distributed algorithms for energy trading
- Cost savings of 45%

Energy Efficiency & Costs Reduction

Triangulum (€30m)

- Funded by EU H2020 SCCSP
- 22 partners
- Energy, Transport & ICT
- 47% carbon emission reduction
- MCC, UoM, MMU, Siemens, etc.

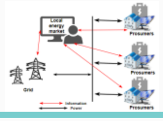
Energy Efficiency demonstrator

Energy-IQ (£2.2m)

- Funded by BEIS UK-Canada
- 8 partners
- Power forward demonstrator project
- Led a deliverable
- Developed AI-based predictive models
    - 88% improvement

Energy Efficiency, Smart contract & data analytics

GM-LEM (£66k)



- Funded by UKRI
- 2 partners
- Consulting for Bruntwood ltd
- On the viability of Greater Manchester local energy market

Energy Efficiency & Costs Reduction

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My Research in AI, Blockchain & Energy

Intelligent Auction Market (£4.7k)

- Funded by EPSRC SuperGen Network
- Travel grant for an intelligent auction-based energy trading
- AI and blockchain in energy network

Energy Efficiency & Costs Reduction

Interlinked Computing (£58k)

- Funded by NWPST
- 4 investigators
- Effect of cobbled systems (systems of systems)
- Security implication of cobbled system
- Smartgrid case study
- UoM, MMU, Lancaster.

Energy Network, Security

Smart EV Charging (£220k)

- KTP Funded by Innovate UK
- With Badger Energy
- To develop AI & blockchain secure smart EV charging infrastructure
- Academic advisor

Energy Efficiency, Smart contract, data analytics, security

Remarkable (£1m)

- Funded by Marie Curie and UKRI
- With Africa and EU countries
- To develop smart and traceable agricultural farming using communication, AI and blockchain.

Smart farming, Smart contract, data analytics, security

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UNIVERSITY OF OXFORD

UNIVERSITY OF BATH

Imperial College London

EPSRC
Engineering and Physical Sciences Research Council

KERI
KOREA ELECTROTECHNOLOGY RESEARCH INSTITUTE

GACHON UNIVERSITY · 가천대학교 · 1939

KONKUK UNIVERSITY KOREA 1931 건국대학교

Kdn
한전KDN

I-ON communications

UKRI Innovate UK

q·energy

Department for Business, Energy & Industrial Strategy

dunsky

Penso Power

CATAPULT Energy Systems

bruntwood

ICONICS

VAYA Energy

hildebrand

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Agenda

- Energy transition
  - P2P-3M (EPSRC); NICE (Innovate UK)
- Energy digitalisation
  - Energy-IQ (BEIS)
- Security, risks and uncertainties to energy transition
  - Interlinked computing (NWPST)
- Outlook

Drivers for energy transition and digitalisation: 3Ds

2D Decentralisation

Centralised generation & transmission results in carbon emissions. **Distributed/Multivector energy system** drives decentralisation, microgrid and prosumers, which could encourage peer-to-peer energy trading.

1D Decarbonisation

Global exercise in reducing carbon footprint drives energy **transition** to sustainable, greener energy systems (Net-zero).

3D Digitalisation

Emergence of smart meters, **IoT** and **data-driven predictive models** enhances energy efficiency and reliability further helping with decarbonisation and costs savings

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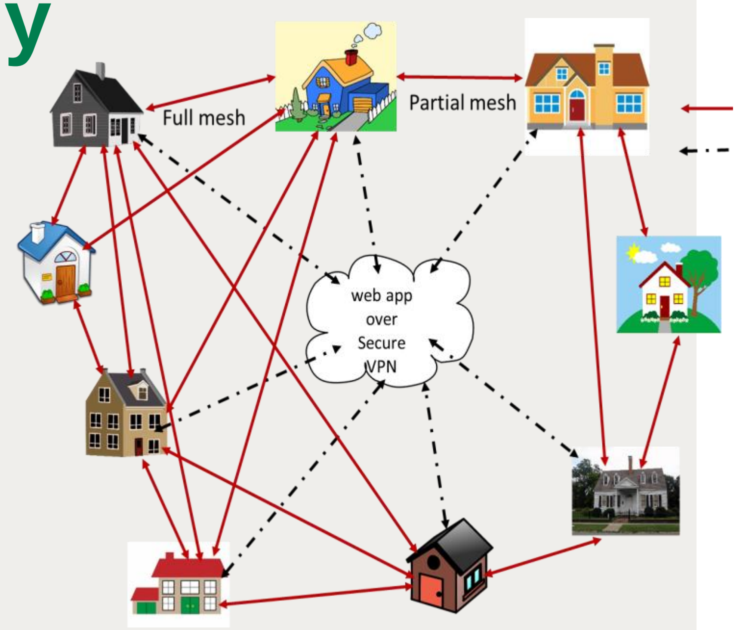
Energy transition: Peer-to-peer energy trading

- Question: How can peer-to-peer energy trading be achieved?
  - Prosumer’s communication, matching, utility maximisation

- Method: To perform fundamental research on establishing communication between prosumers, matching their resources and maximising their utility while trading energy

- Impact: Environment - reduce carbon towards net-zero goal; Economic - cost savings; Society - encourage local energy consumption



UK- S.Korea

£2m
Budget

9 Delivery partners

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Jogunola, O., Adebisi, B., Anoh, K., Ikpehai, A., Hammoudeh, M., & Harris, G. (2022). Multi-Commodity Optimisation of Peer-to-Peer Energy Trading Resources in Smart Grid. Journal of Modern Power Systems and Clean Energy.
Jogunola, O., Wang, W., & Adebisi, B. (2020). Prosumers matching and least-cost energy path optimisation for peer-to-peer energy trading. IEEE Access, 8, 95266-95277.
Jogunola, O., Adebisi, B., Anoh, K., Ikpehai, A., Hammoudeh, M., Harris, G., & Gacanin, H. (2018). Distributed adaptive primal algorithm for P2P-ETS over unreliable communication links. Energies, 11(9), 2331.

Energy Transition - NicE: Nigeria Intelligent Clean Energy Marketplace

- Aim: To provide access to affordable and clean energy to local communities in Nigeria through the implementation of FPP and P2P-ETS
- Method: To set up a digital twin of the model at MMU for optimisation and scalability
- Impact:
  - Environment – reduce carbon towards net-zero goal
  - Economic – cost savings
  - Society – encourage energy efficiency

UK- Nigeria

£0.6m **Budget**

3 **Delivery partners**

Tsado, Y., **Jogunola, O.,** Nawaz, R., Gui, G., & Adebisi, B. (2021). Quantifying Self-consumption and Flexibility Provision through Battery Storage, a Deep Reinforcement Learning Approach. ICFNDs.

Jogunola, O., Tsado, Y., Nawaz, R., & Adebisi, B. (2021). Energy Trading Strategy, a Deep Reinforcement Learning Approach. EPEC.

Tsado, Y., **Jogunola, O.,** Olatunji, F. O., & Adebisi, B. (2022, October). A digital twin integrated cyber-physical systems for community energy trading. *SmartGridComm*. IEEE.

NicE: Nigeria Intelligent Clean Energy Marketplace

Capital Science Academy Abuja

Neighbouring Dafara Community

UK- Nigeria

£0.6m
Budget

3 Delivery partners

https://guardian.ng/energy/uk-based-energy-solutions-company-provides-nigerian-community-with-24-7-renewable-energy/

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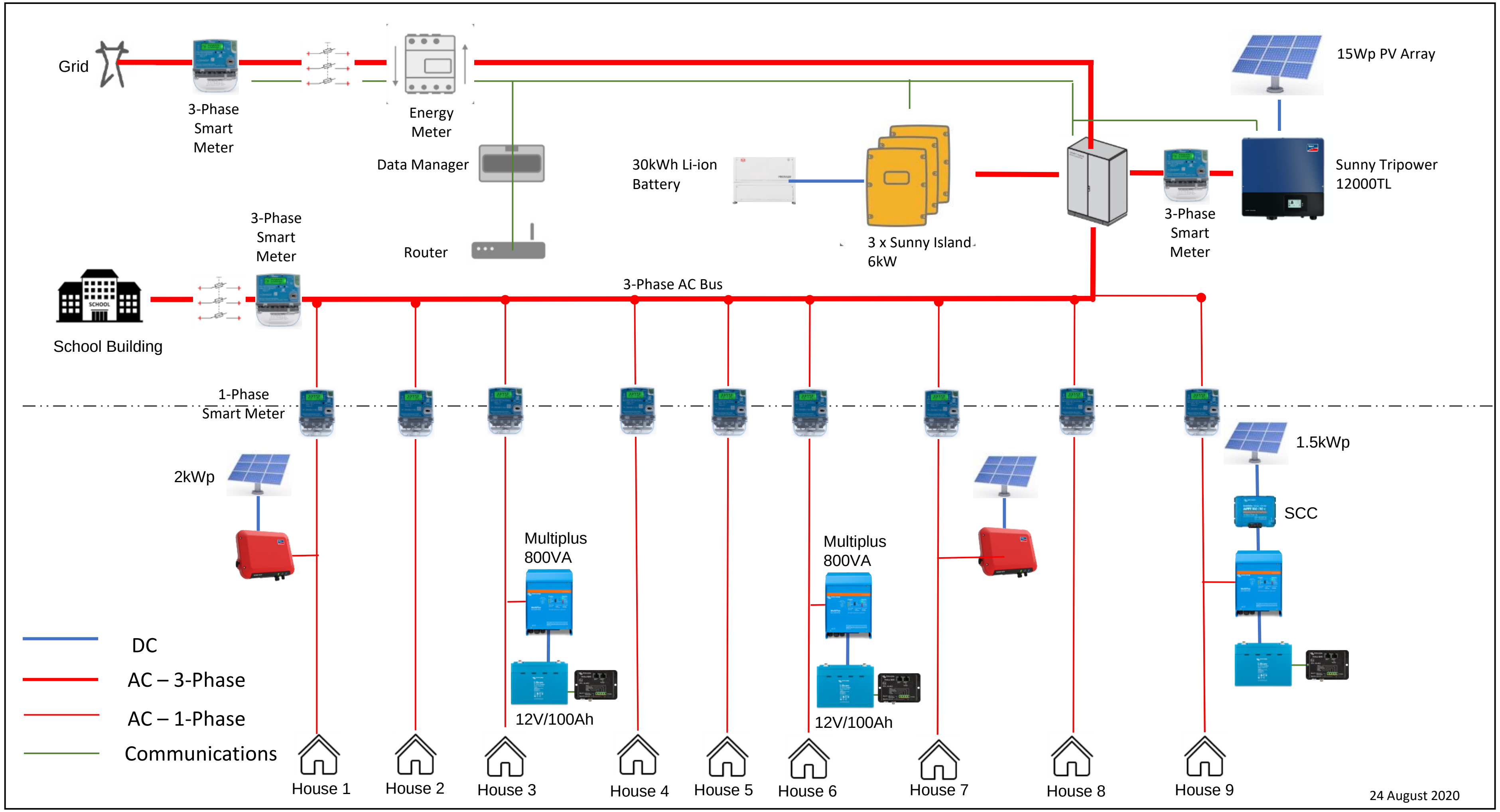
NICE pilot architecture at Kuje, Abuj



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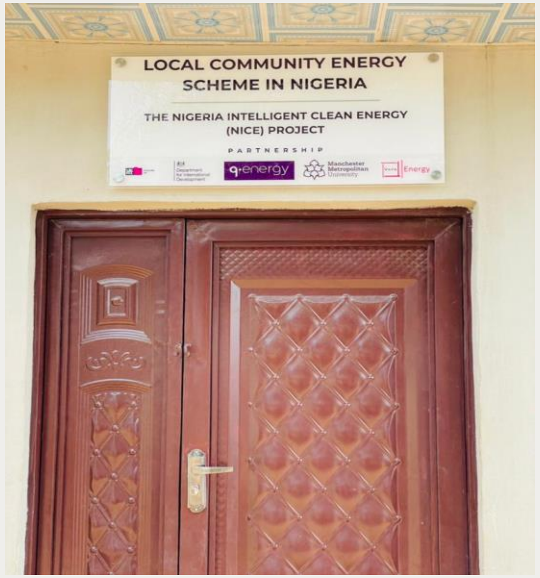
NICE: Community installations



UK- Nigeria

£0.6m
Budget

3 Delivery partners

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Innovate UK

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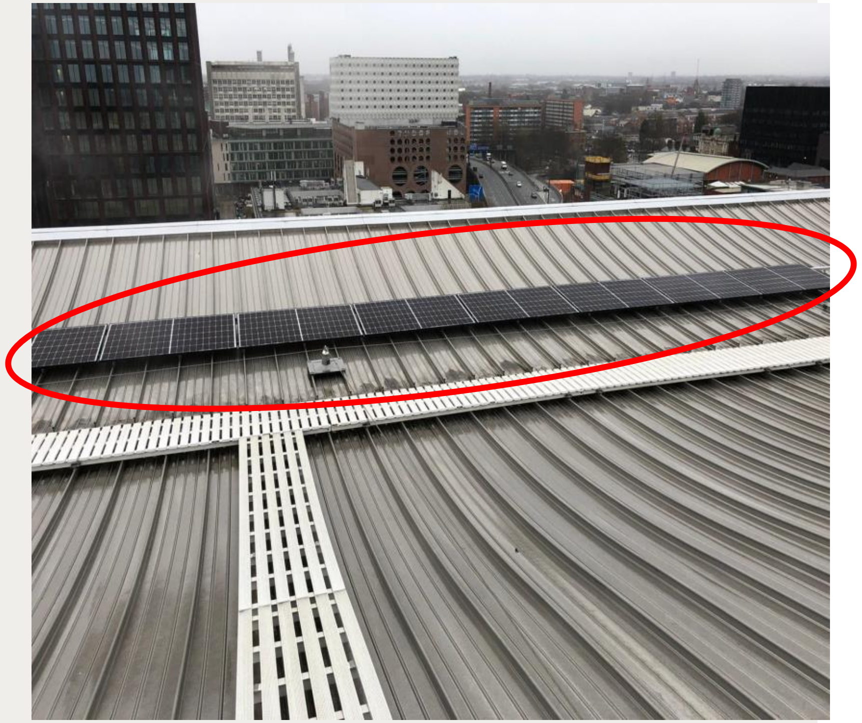
NICE: MMU lab model & installations

R-Prosumer
Battery, Load and PV

R-Prosumer
Battery and Load

C-Prosumer
Battery, Load and PV

R-Prosumer
PV and Load



4 x REC solar 325W solar panels = 1.3kWp array for each prosumer

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UKRI Innovate UK

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VAYA Energy

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Drivers for energy transition and digitalisation: 3Ds

2D

Decentralisation

Centralised generation & transmission results in carbon emissions. **Distributed/Multivector energy system** drives decentralisation, microgrid and prosumers, which could encourage peer-to-peer energy trading.

1D

Decarbonisation

Global exercise in reducing carbon footprint drives energy **transition** to sustainable, greener energy systems (Net-zero).

3D

Digitalisation

Emergence of smart meters, **IoT** and **data-driven predictive models** enhances energy efficiency and reliability further helping with decarbonisation and costs savings

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Research on Energy digitalisation: Energy-IQ

- Question: How can smart services accelerate flexibility provisions for costs savings for SMEs and domestic energy users?
  - To trial smart energy services for cost savings

- Method: To investigate AI and smart contract for energy market
  - To develop a predictive analytics framework for demand consumption

- Impact: Environment - reduce carbon towards net-zero goal; Economic - cost savings; Society – encourage energy efficiency

UK- Canada

£2.2m
Budget

8 Delivery partners

Jogunola, O., Adebisi, B., Ikpehai, A., Popoola, S. I., Gui, G., Gacanin, H., & Ci, S. (2020). Consensus Algorithms and Deep Reinforcement Learning in Energy Market: A Review. *IEEE Internet of Things Journal*.

Tsado, Y., **Jogunola, O.,** Nawaz, R., Gui, G., & Adebisi, B. (2021). Quantifying Self-consumption and Flexibility Provision through Battery Storage, a Deep Reinforcement Learning Approach. ICFNDs.

Jogunola, O., & Adebisi, B., Hoang, K. V., Tsado, Y. & Popoola, S. I. (2022). CBLSTM-AE: A Hybrid Deep Learning Framework for Predicting Energy Consumption. Energies.

Jogunola, O., Tsado, Y., Nawaz, R., & Adebisi, B. (2021). Energy Trading Strategy, a Deep Reinforcement Learning Approach. EPEC

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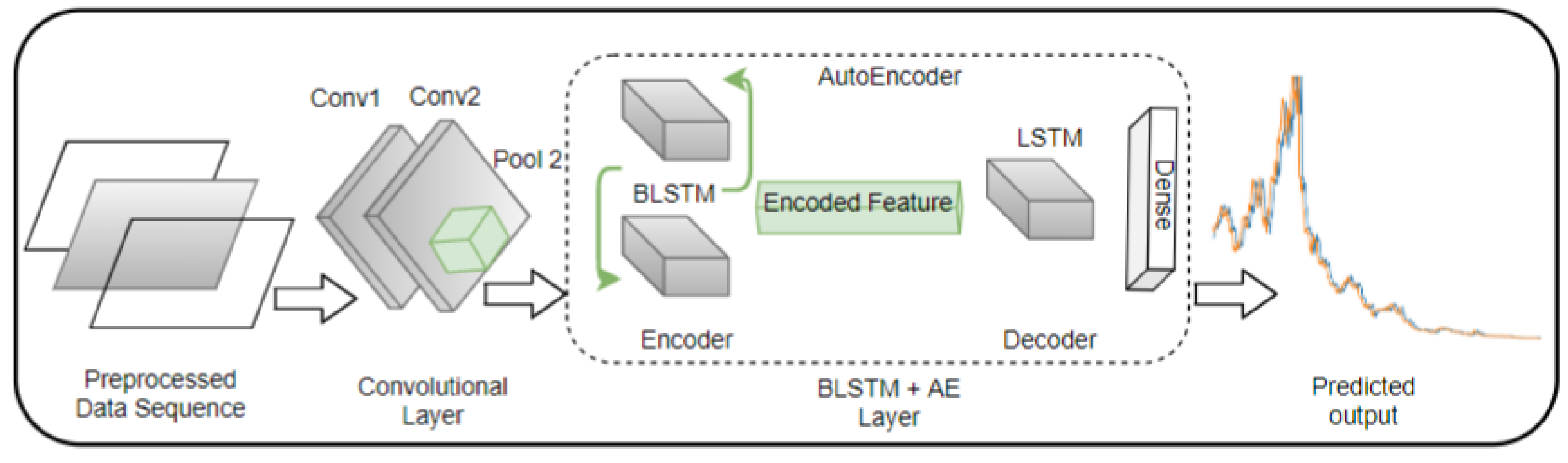
Predictive framework

Aim: To develop a predictive model for energy consumption prediction

Methodology: Deep learning: LSTM + AE + CNN



Proposed CBLSTM-AE framework

Algorithm 1: CBLSTM-AE Algorithm

Input X
Output d
Initialise ω
for $i = 1 \in n$ **do**
  for $j = 1 \in m$ **do**
    calculate P_i from (4)
    $i_t = \sigma(\overleftrightarrow{W_{pi}Pl} + \overleftrightarrow{W_{hi}h_{t-1}} + W_{ci} \cdot c_{t-1} + \overleftrightarrow{b_i})$
    $f_t = \sigma(\overleftrightarrow{W_{pf}Pl} + \overleftrightarrow{W_{hf}h_{t-1}} + W_{cf} \cdot c_{t-1} + \overleftrightarrow{b_f})$
    $o_t = \sigma(\overleftrightarrow{W_{po}Pl} + \overleftrightarrow{W_{ho}h_{t-1}} + W_{co} \cdot c_{t-1} + \overleftrightarrow{b_o})$
    $c_t = f_t \cdot c_{t-1} + i_t \cdot \sigma(W_{pc}p_t + W_{hc}h_{t-1} + b_c)$
    $h_1 = o_1 \cdot \sigma(c_1)$
  end
  $\bar{y} = \sigma(\overleftrightarrow{W_y h_1} + b_y)$
  for $j = 1 \in m$ **do**
    $i_t = \sigma(W_{yi}\bar{y}l + W_{hi}h_{t-1} + W_{ci} \cdot c_{t-1} + b_i)$
    $f_t = \sigma(W_{yf}\bar{y}l + W_{hf}h_{t-1} + W_{cf} \cdot c_{t-1} + b_f)$
    $o_t = \sigma(W_{po}\bar{y}l + W_{ho}h_{t-1} + W_{co} \cdot c_{t-1} + b_o)$
    $c_t = f_t \cdot c_{t-1} + i_t \cdot \sigma(W_{pc}p_t + W_{hc}h_{t-1} + b_c)$
    $h_1 = o_1 \cdot \sigma(c_1)$
  end
  $\hat{y} = \sigma(W_y h_t + b_y)$
  $\bar{d}_i^k = \sum_j w_{ji}^k - 1(\sigma(\hat{y}_i^{k-1}) + b_i^{k-1})$
end
$d = \{\bar{d}\}$

Result: Performance improvement in computation time of 56% and mean squared error of 80% to benchmark

Jogunola, O., & Adebisi, B., Hoang, K. V., Tsado, Y. & Popoola, S. I. (2022). CBLSTM-AE: A Hybrid Deep Learning Framework for Predicting Energy Consumption. Energies.

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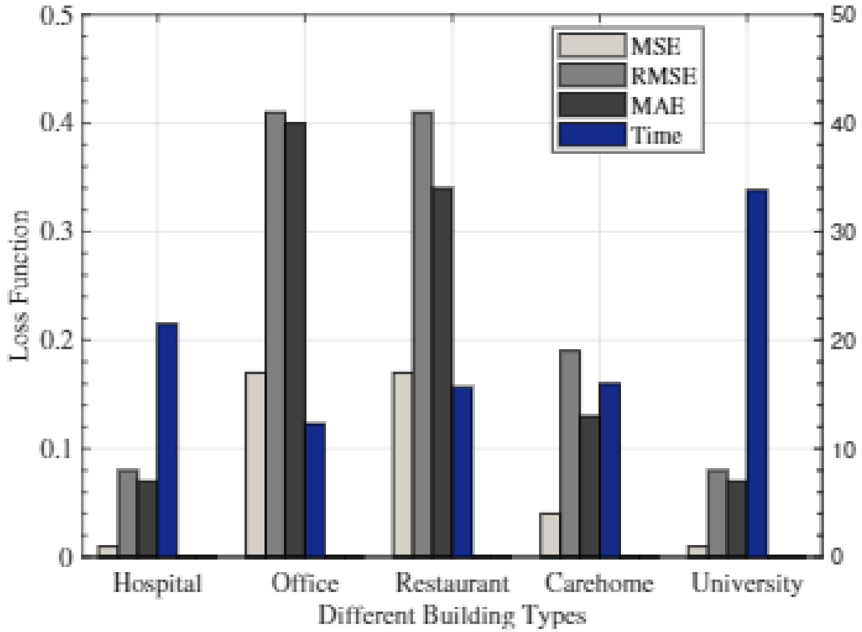
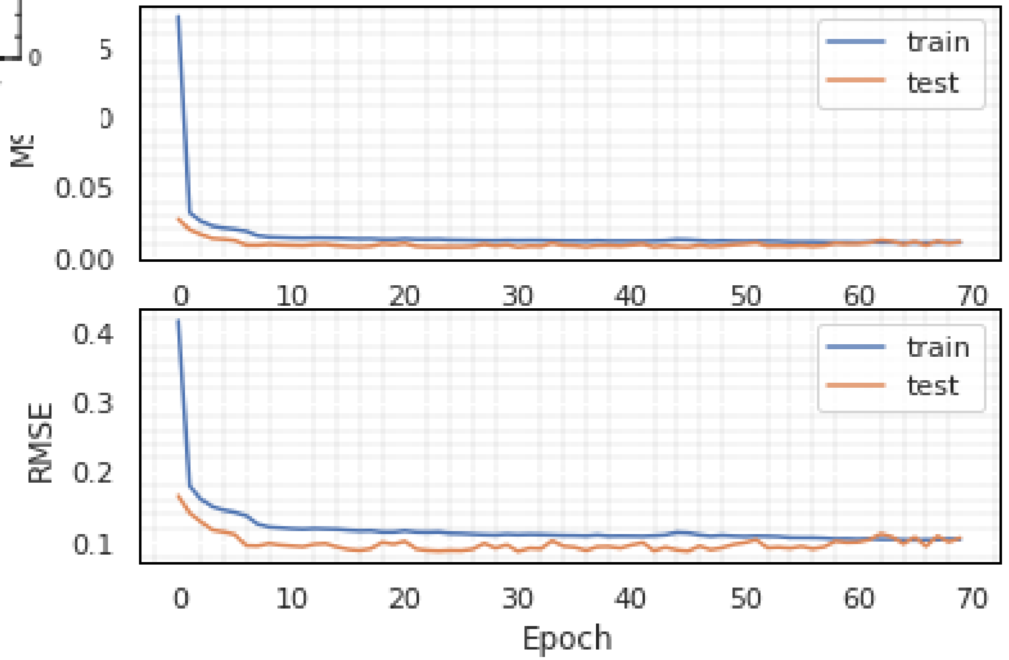
Results



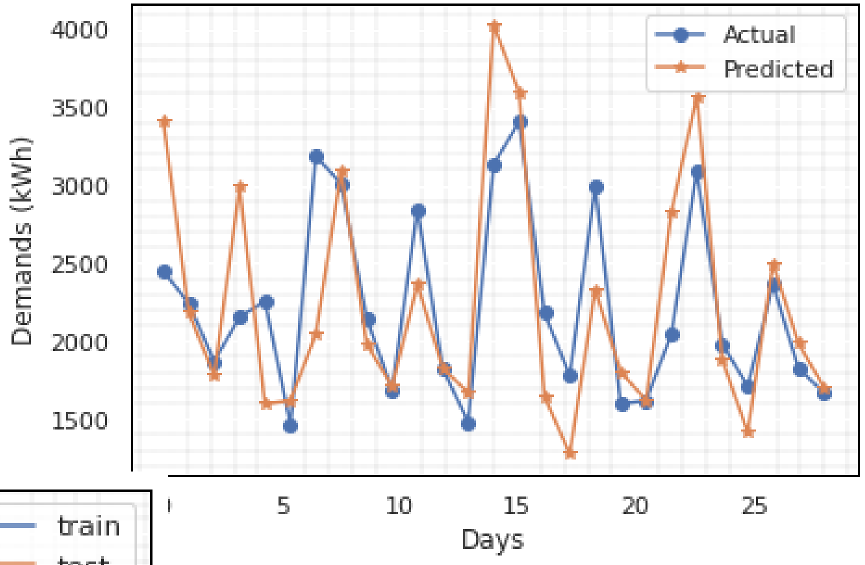
Different Energy dataset

- Increase in length of data result in
  - Increase in computation time
  - Decrease in measured loss

- To show the skilfulness of th proposed solution
- Training and validation loss for MSE and RMSE
- MSE of 0.01, RMSE of 0.09



Training and validation loss



Actual and predicted

- To illustrate the predictive fit with actual data
- A months' prediction showing good fit

Jogunola, O., & Adebisi, B., Hoang, K. V., Tsado, Y. & Popoola, S. I. (2021). CBLSTM-AE: A Hybrid Deep Learning Framework for Predicting Energy Consumption. IEEE Internet of Things (under review).

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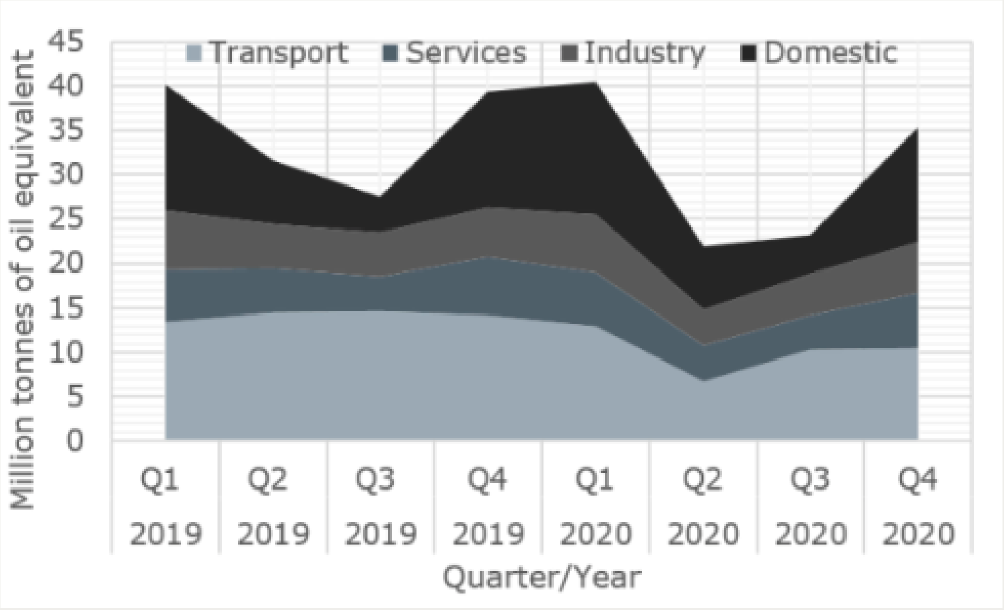
Post-Covid energy consumption forecasting

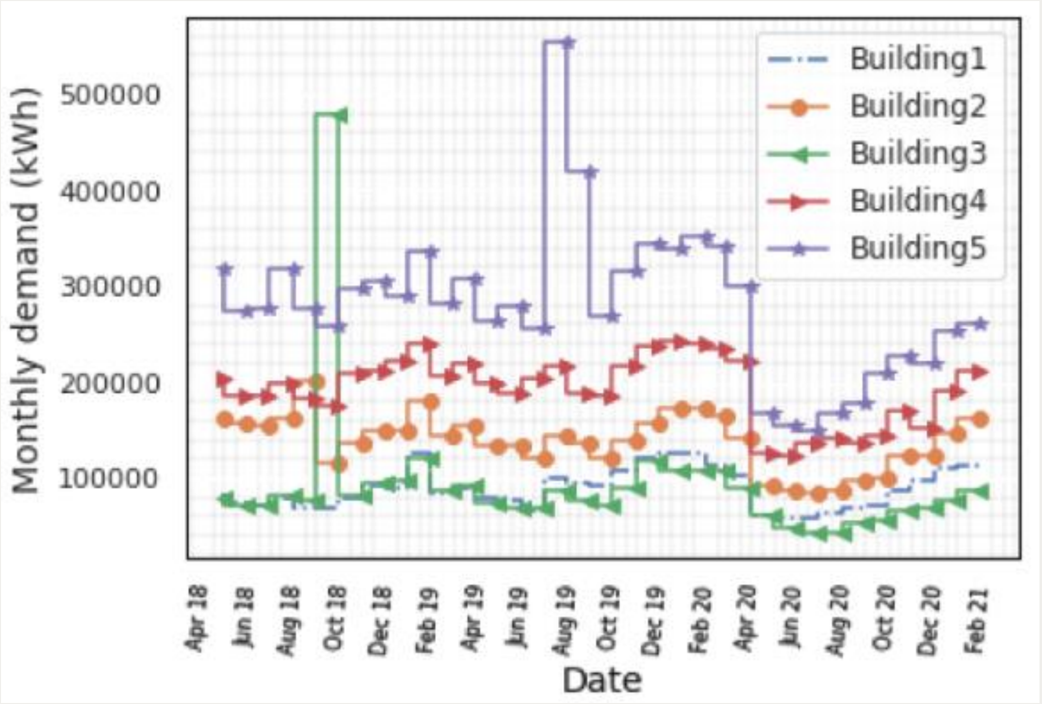
Aim: To answer the key question of what commercial energy and occupancy patterns be in a post-covid world and its impact on smart energy service landscapes

Methodology: Review and predictive analysis

BEIS: UK Energy consumption by sector



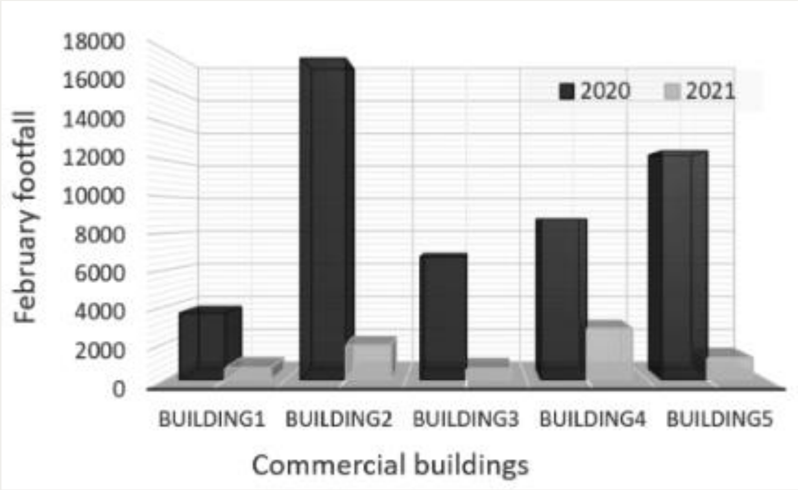
Sample energy data for 5 commercial buildings



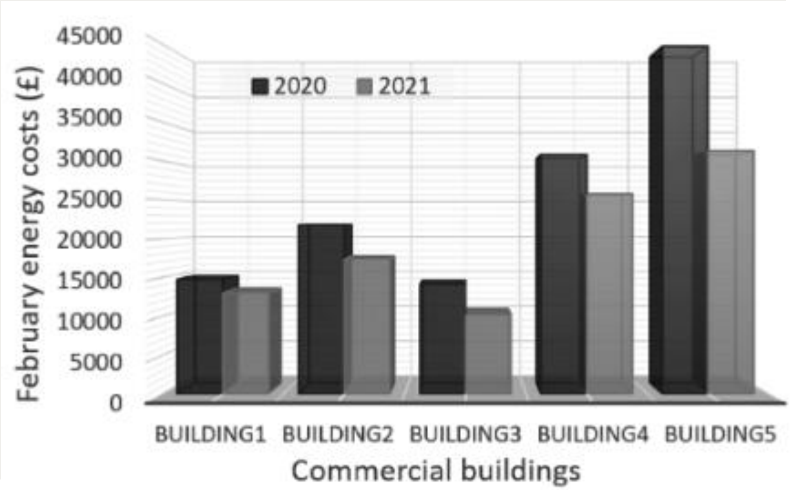
Result: To inform policy on energy and intervention towards net-zero carbon, costs savings

Jogunola, O., Morley, C., Akpan, I. J., Tsado, Y., Adebisi, B., & Yao, L. (2022). Energy consumption in commercial buildings in a post-covid-19 world. *IEEE Engineering Management Review*, *50*(1), 54-64.

Results

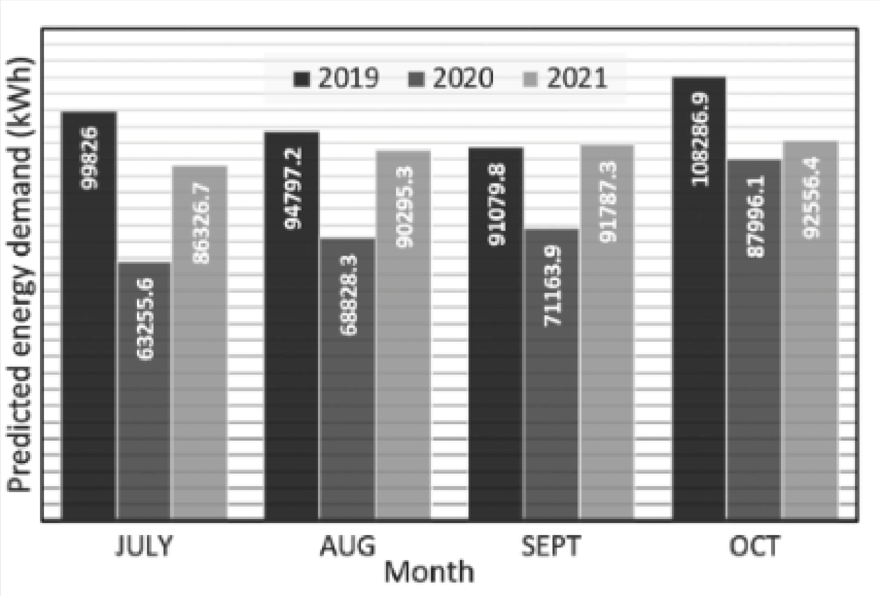


- **2021 higher than 2020 and 2019**
- **29%, 38%, 45%, 37% higher than covid**
- **8%, 19%, 39%, 1% higher than pre-covid**



February occupancy: Average of 10% of 2020 footfall

February costs: Average of 80% of 2020 costs



4-month energy prediction for building 1

Jogunola, O., Morley, C., Akpan, I. J., Tsado, Y., Adebisi, B., & Yao, L. (2022). Energy consumption in commercial buildings in a post-covid-19 world. *IEEE Engineering Management Review*, *50*(1), 54-64.

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Security, risks and uncertainties to Energy Transition

Vulnerabilities in SCADA Systems

- Insecure data communication between SCADA and the whole energy system

Technology risks

- Outdated and insecure grid infrastructure
- AI, blockchain, etc

Supply chain

- System of system and supply chain risks

Batteries and car chargers

- Insecure battery management systems
- Vulnerabilities in firmware and lack of industry standards

Acceptance and regulatory requirements

- Behavioural change
- Legal requirements around licensing

Smart home and building IoT

- IoT increased attack surfaces
- Data collection and processing

RUSI (2022), Securing a Net-zero Future. Available https://static.rusi.org/305-EI-Cyber-Risks.pdf

Yuan, H., & Li, S. (2022, June). Cyber Security Risks of Net Zero Technologies. In *2022 IEEE Conference on Dependable and Secure Computing (DSC)* (pp. 1-11). IEEE.

Jogunola, O., Ajagun, A. S., Tushar, W., Olatunji, F. O., Yuen, C., Morley, C., ... & Shongwe, T. (2024). Peer-to-Peer Local Energy Market: Opportunities, Barriers, Security and Implementation Options. *IEEE Access*.

Cyber Security Threats to Energy Transition

IOT SECURITY

Hackers Earn $1.3M for Tesla, EV Charger, Infotainment Exploits at Pwn2Own Automotive

Participants have earned more than $1.3 million for hacking Teslas, EV chargers and infotainment systems at Pwn2Own Automotive.

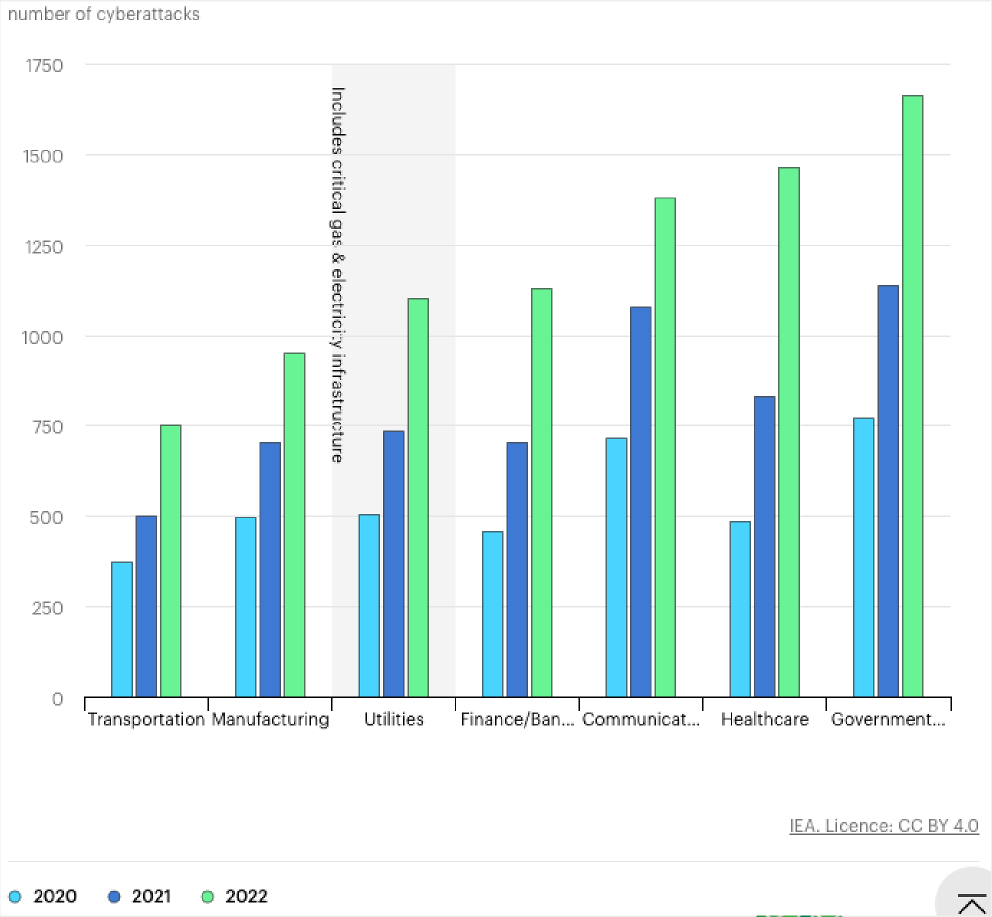
By Eduard Kovacs
January 26, 2024

/ News / "Top Python Developers Hacked In Sophisticated Supply Chain Attack"

"Top Python Developers Hacked in Sophisticated Supply Chain Attack"

Checkmarx reports that multiple Python developers, including a Top.gg maintainer, were infected with information-stealing malware after downloading a malicious clone of a popular tool. Colorama, a tool that makes ANSI escape character sequences work on Windows, has over 150 million monthly downloads. The

The average number of weekly cyberattacks per organisation in selected industries



Cyber Security – Interlinked Computing: System of System Security

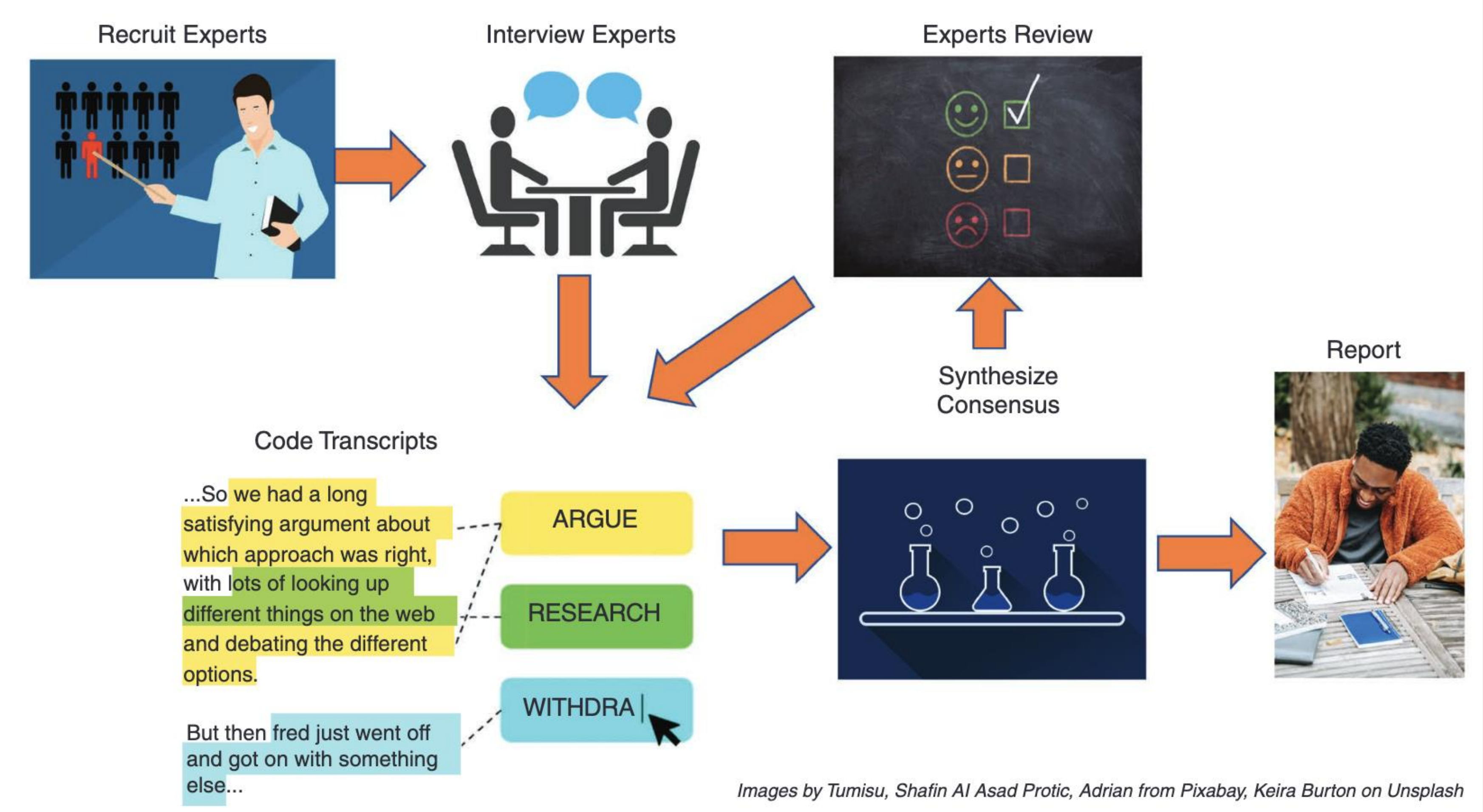


FIGURE 1. The Delphi process.

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C. Weir, A. Dyson**, O. Jogunola,** L. Dennis and K. Paxton-Fear, "Interlinked Computing in 2040: Safety, Truth, Ownership, and Accountability," in Computer, vol. 57, no. 1, pp. 59-68, Jan. 2024, doi: 10.1109/MC.2023.3318377.

Future outlook – Interlinked computing

TABLE 2. Agreement with statements.

	Forecast	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
F1	Cutting corners in safe AI	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	... leading to a megadeath incident	White	Blue	Amber	White	Amber	Amber	Amber	Blue	Amber	Amber	White	White
	... due to regulatory capture	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	White	Blue
	... which has developed exponentially	Amber	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
F2	Quantum processing only just being used	White	Blue	Amber	White	Amber	White	White	White	Blue	Amber	Blue	Amber
F3	Difficulty distinguishing truth from fiction	Blue	White	Blue	White	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
F3	Tokenization for ownership of web assets	White	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	White	Blue	White
F5	Cannot distinguish accidents from incidents	Blue	White	Blue	White	White	White	Blue	Amber	White	Amber	Blue	Blue
	... systems beyond human understanding	Blue	White	Blue	Amber	Blue	White	Blue	Blue	Blue	Blue	Blue	White
	... with more accidents due to complexity	Blue	Blue	White	White	Amber	White	Blue	Amber	White	Blue	White	Blue

Blue: agree; white: no opinion or unsure; amber: disagree.

C. Weir, A. Dyson**, O. Jogunola,** L. Dennis and K. Paxton-Fear, "Interlinked Computing in 2040: Safety, Truth, Ownership, and Accountability," in Computer, vol. 57, no. 1, pp. 59-68, Jan. 2024, doi: 10.1109/MC.2023.3318377.

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Thank You!

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