Granular technologies to accelerate decarbonisation

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‘granular’

small unit size

low unit cost

modular

** replication **

‘lumpy’

large unit size

high unit cost

indivisible

** up-scaling**

Innovation and investment strategies weighted towards granular technologies support **accelerated decarbonisation**

More granular technologies

... deploy faster
... are less risky
... learn quicker

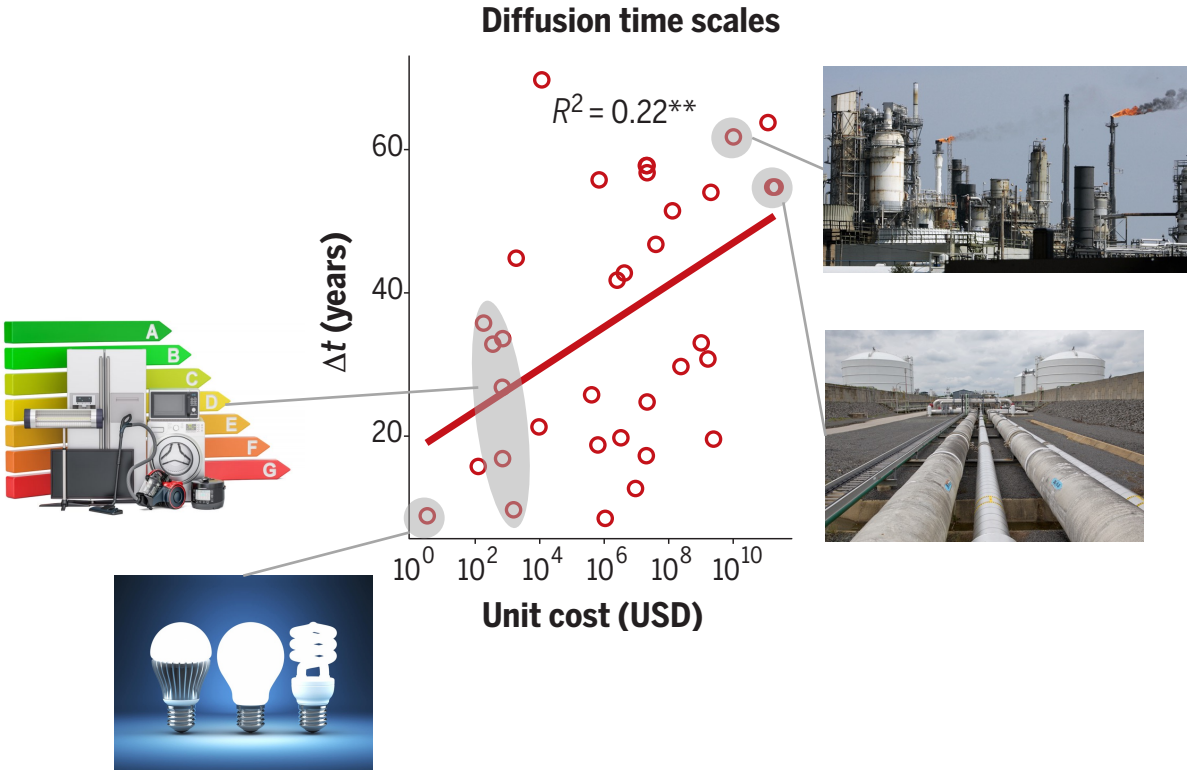
... offer more efficiency gains
... are less susceptible to lock-in

... are more equitably accessible
... create more net jobs
... yield higher social returns

Progress towards net-zero

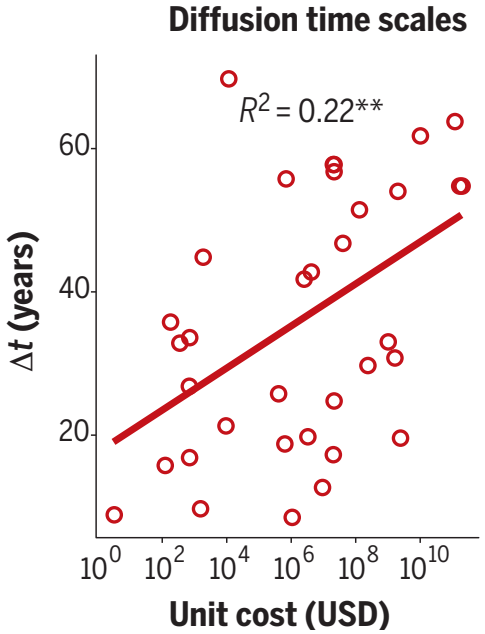
Source: Wilson, Grubler et al. (2020). *Science* 368(6486): 36-39.

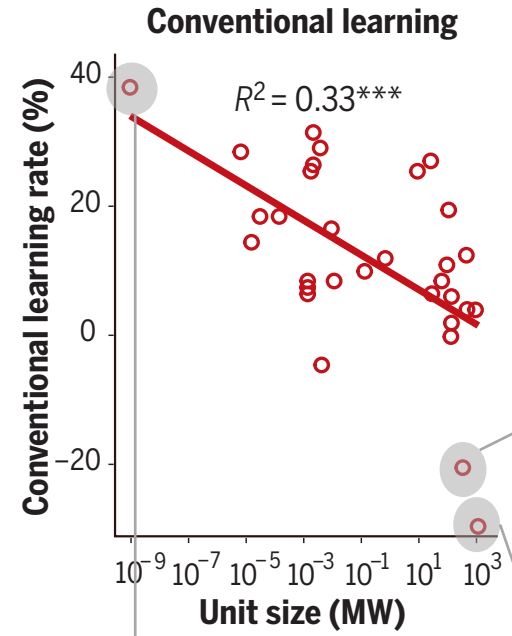
Historical analysis of different energy technologies shows: (1) more *granular* technologies … deploy faster

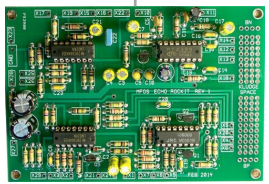


Source: Wilson, Grubler et al. (2020). *Science* 368(6486): 36-39.

Historical analysis of different energy technologies shows: (2) more *granular* technologies … improve quicker



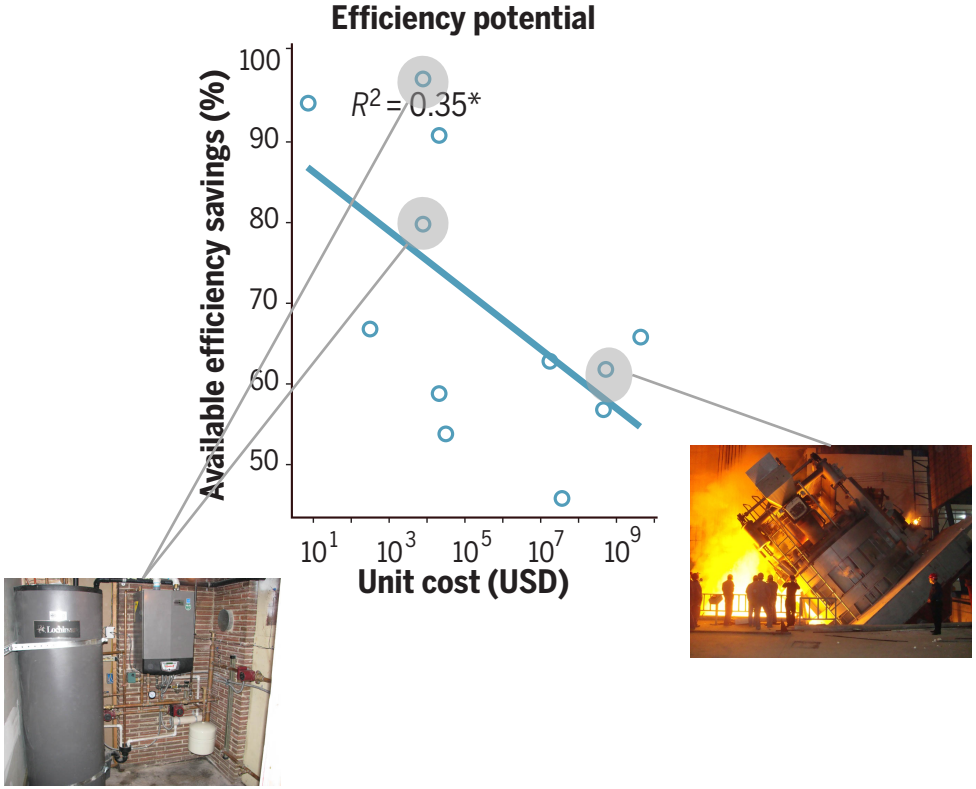




FGD: flue gas desulphurisation

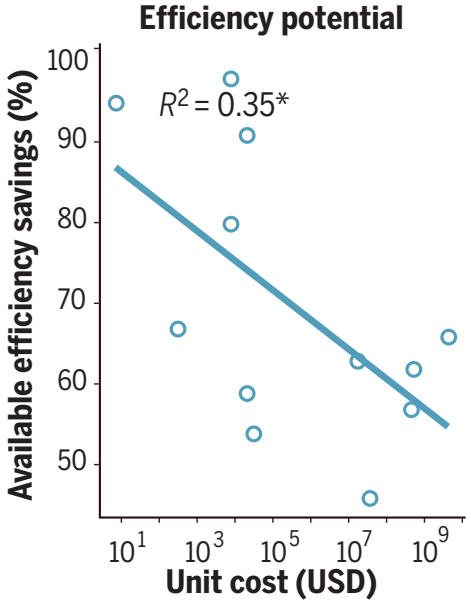
Source: Wilson, Grubler et al. (2020). *Science* 368(6486): 36-39.

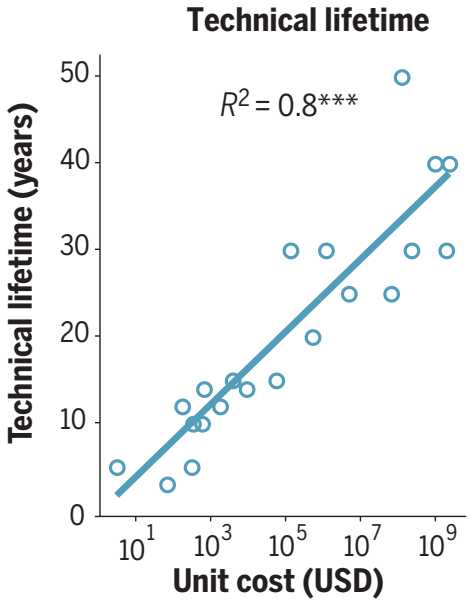
Historical analysis of different energy technologies shows: (3) more *granular* technologies … offer more efficiency gains

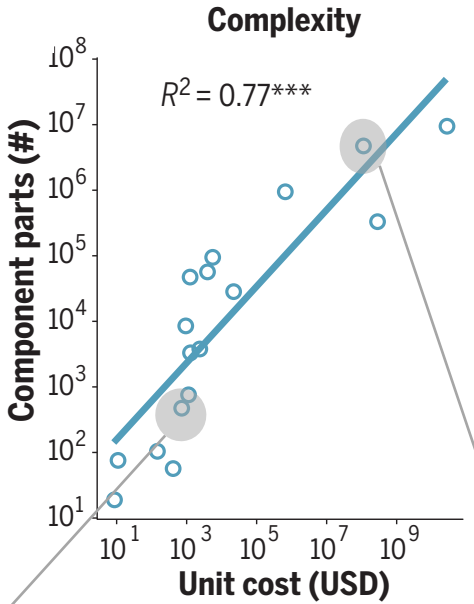


Source: Wilson, Grubler et al. (2020). *Science* 368(6486): 36-39.

Historical analysis of different energy technologies shows: (4) more *granular* technologies … have lower lock-in risks

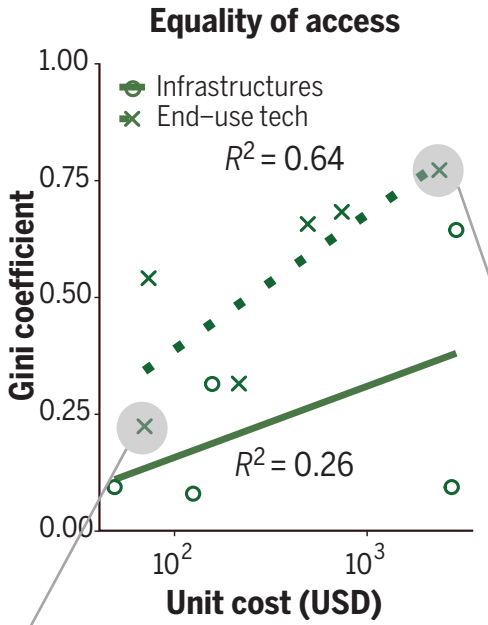




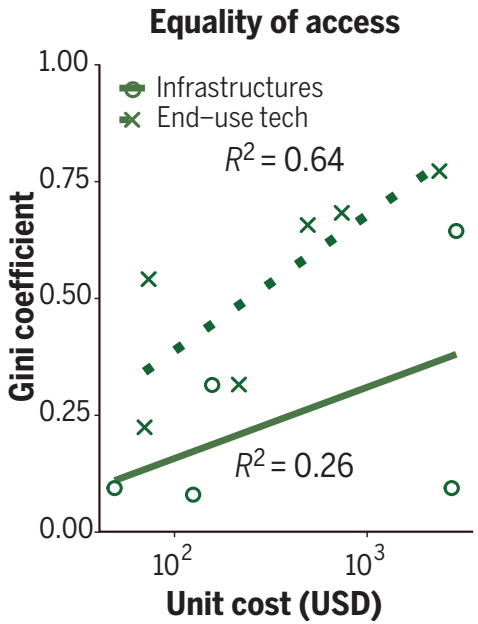


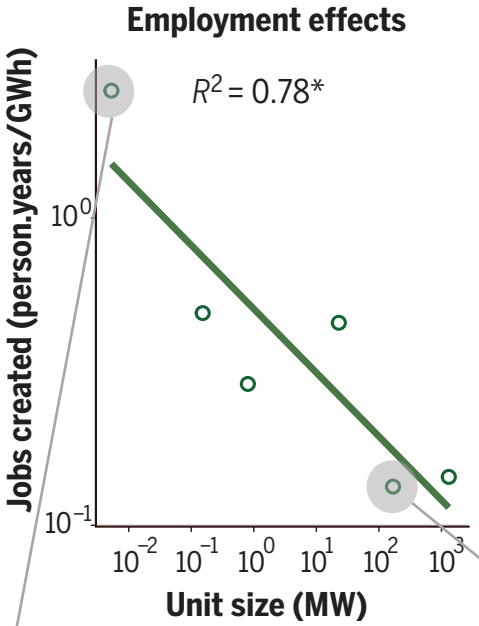
Source: Wilson, Grubler et al. (2020). *Science* 368(6486): 36-39.

Historical analysis of different energy technologies shows:
(5) more *granular* technologies … are more widely accessible



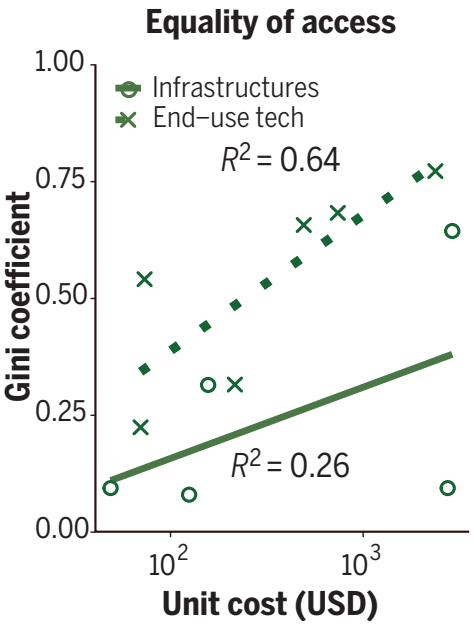
Historical analysis of different energy technologies shows: (6) more *granular* technologies … create more net jobs

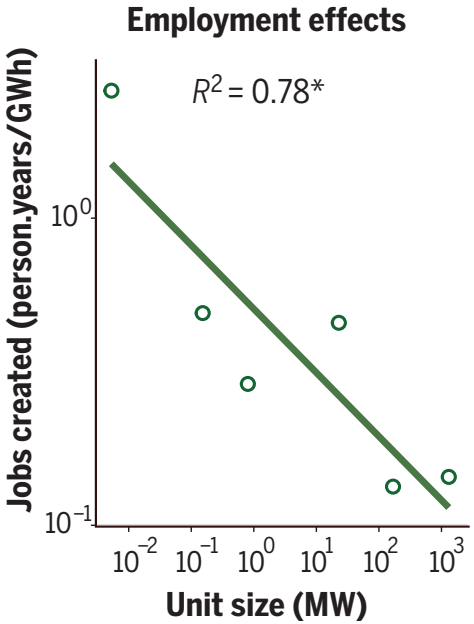


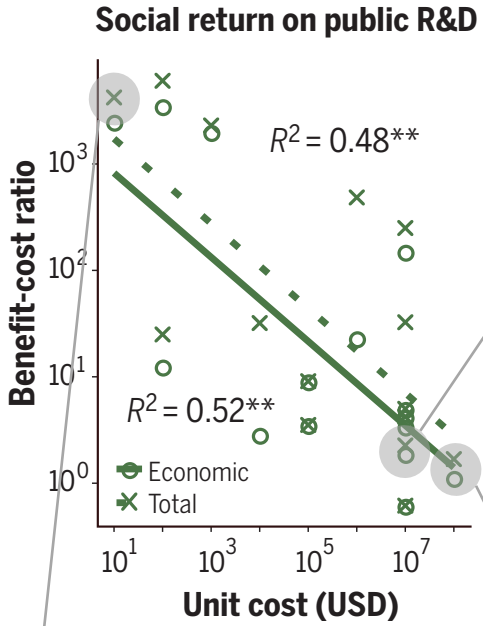


Source: Wilson, Grubler et al. (2020). *Science* 368(6488): 36-39.

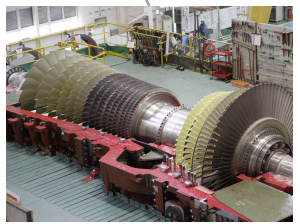
Historical analysis of different energy technologies shows: (7) more *granular* technologies … yield higher social returns







FGD



Source: Wilson, Grubler et al. (2020). *Science* 368(6486): 36-39.

The advantages of granularity are contingent on ... **substitutability**, **system integration** and **standardisation**

More granular technologies

... deploy faster
... are less risky
... learn quicker

... offer more efficiency gains
... are less susceptible to lock-in

... are more equitably accessible
... create more net jobs
... yield higher social returns

substitutability

system integration

standardisation

Innovation and investment strategies weighted towards granular technologies support **accelerated decarbonisation**

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... deploy faster
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... create more net jobs
... yield higher social returns

more speed

more robustness

more legitimacy

Progress towards net-zero

AND

Funding portfolio evaluation

Source: Wilson, Grubler et al. (2020). *Science* 368(6486): 36-39.

Low-Carbon Technologies & Infrastructures

low unit cost
small unit size
modular

more granular

more lumpy

high unit cost
large unit size
non divisible

- Rapid Deployment
- Job Creation
- Low Risk
- Distributed Benefits

Objectives of Green Recovery Spending

Analysis of Four Countries' Green Recovery Funding Programmes (totalling £72.9 bn)

perform better against objectives

more granular

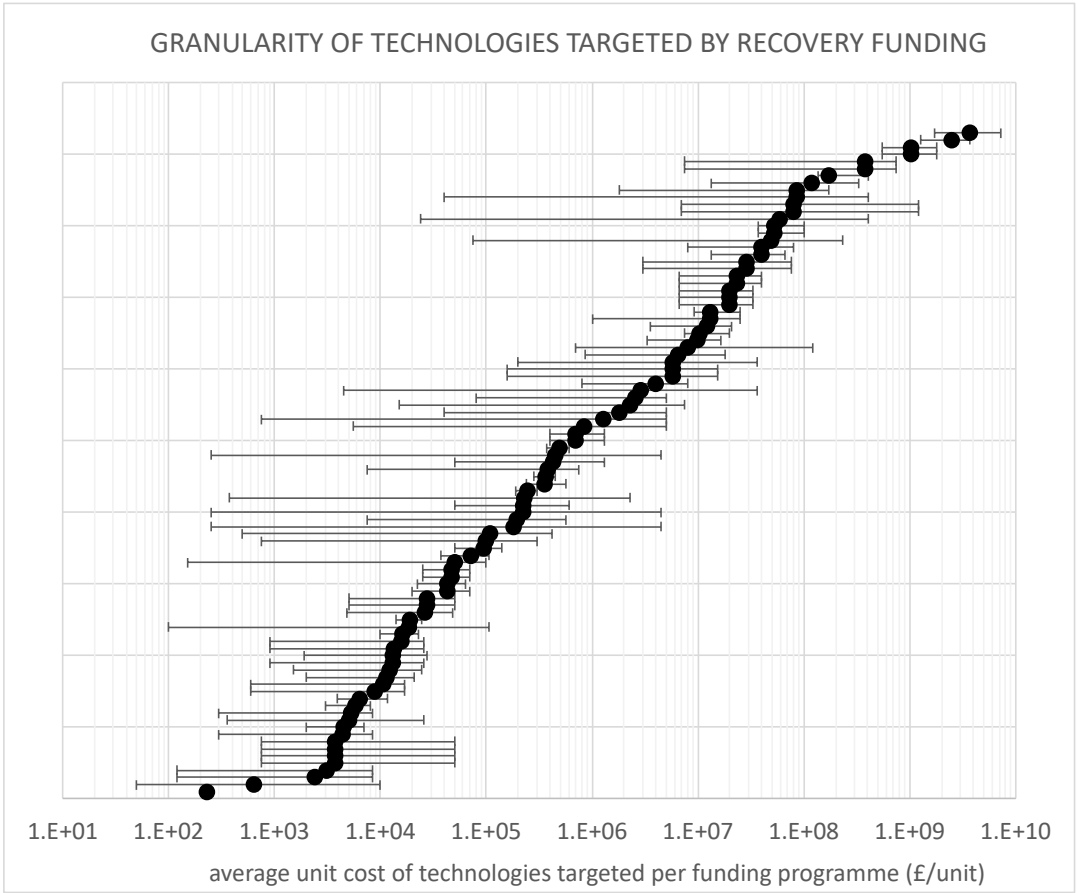
more lumpy

perform worse against objectives

Source: Wilson et al (2023). *Joule* 7(6): 1206-1226.

Icons from: https://pixabay.com

Granularity of low-carbon technologies and infrastructures targeted by **green recovery funding** varies widely



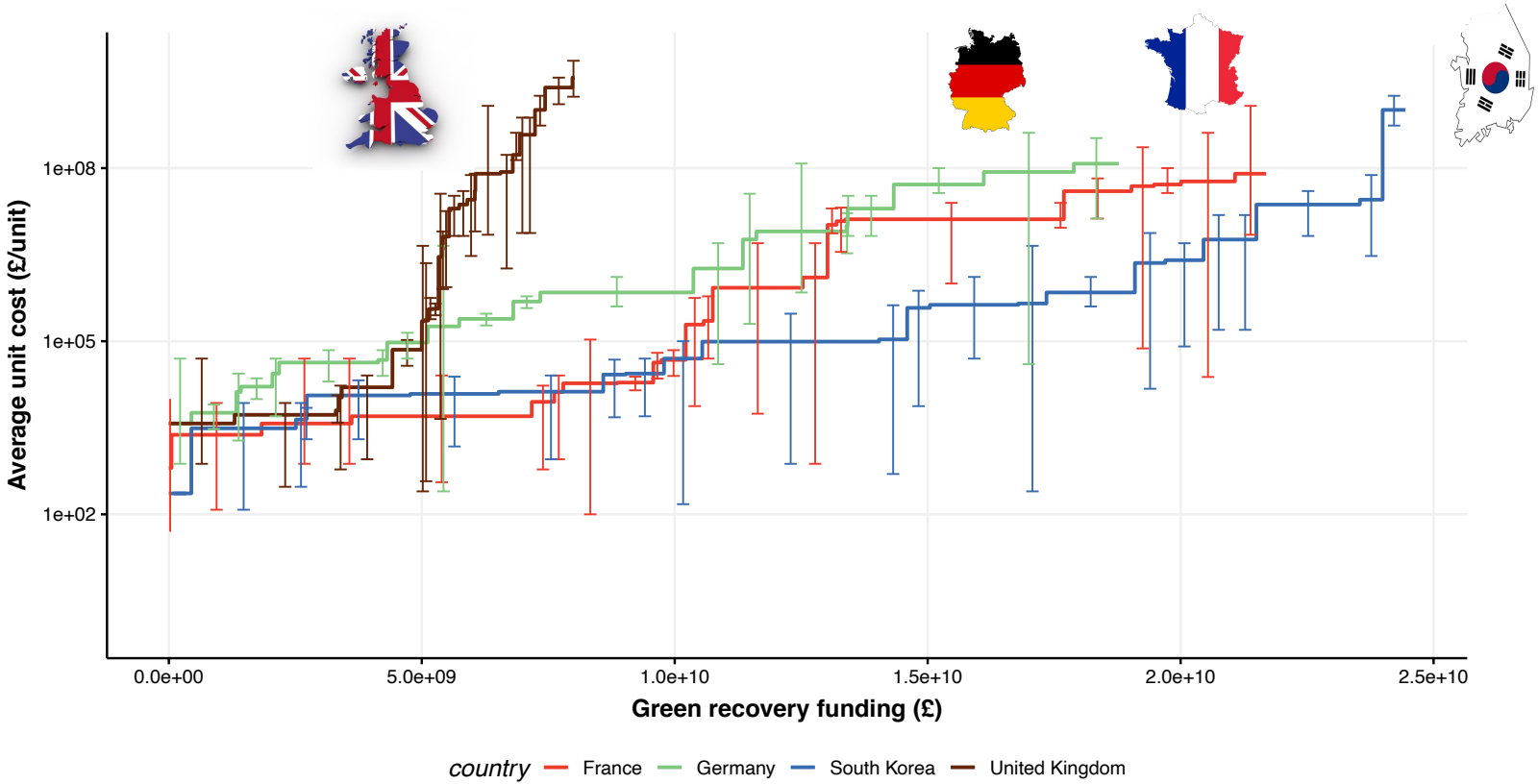
solar PV systems
[£4500/unit]

smart meters
[£230/unit]

nuclear power
[>£1bn/unit]

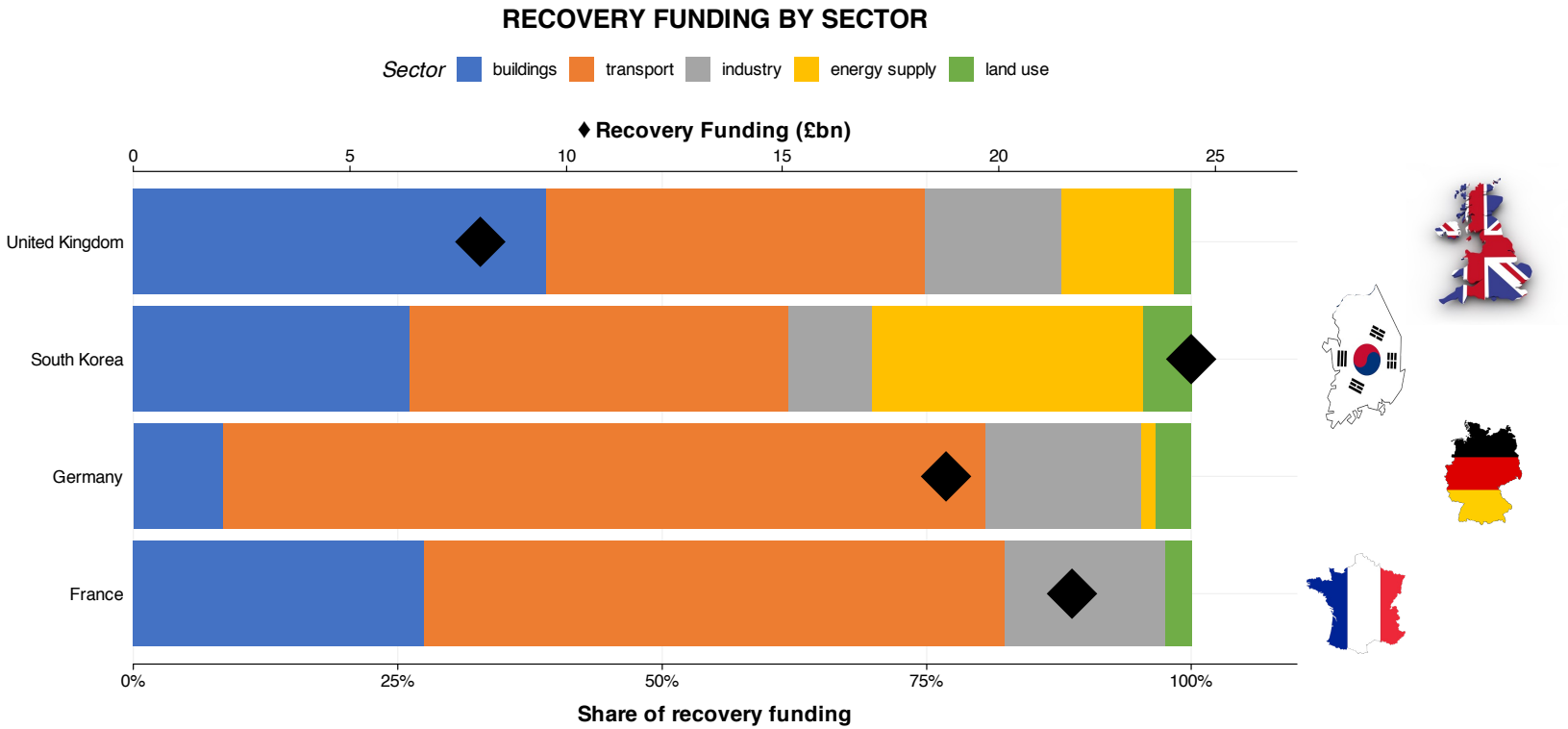
large-scale CCS
[>£1bn/unit]

Countries' green recovery funding programmes have different weightings towards granular low-carbon technologies



Source: Wilson et al (2023). *Joule* 7(6): 1206-1226.

Funding portfolios are weighted towards economic sectors in line with national priorities



Source: Wilson et al (2023). *Joule* 7(6): 1206-1226.

Funding portfolios distributed over **larger numbers** of smaller units have numerous advantages




Total recovery funding	£19bn	£8bn	£22bn	£24bn
Est. # of units funded	0.4m	0.8m	2.2m	3.2m

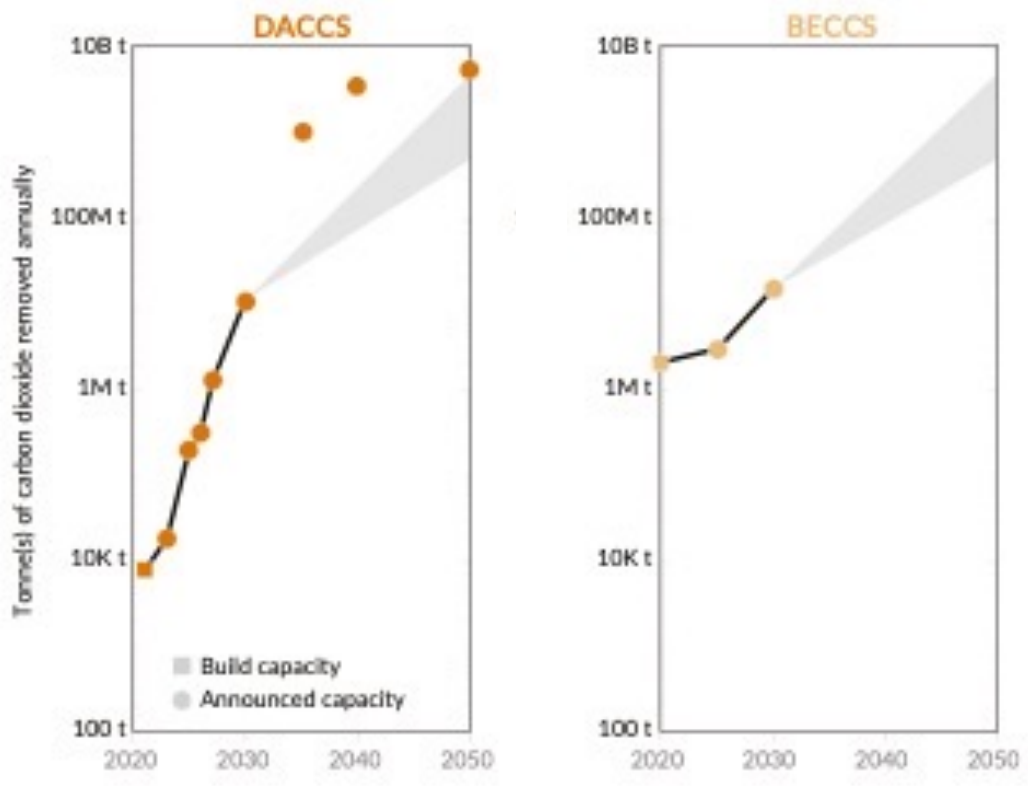
- strategic objectives
- industrial clusters
- unit scale economies
- (no granular alternatives)

- faster deployment
- lower risk
- more direct beneficiaries
- more net jobs

Source: Wilson et al (2023). *Joule* 7(6): 1206-1226.

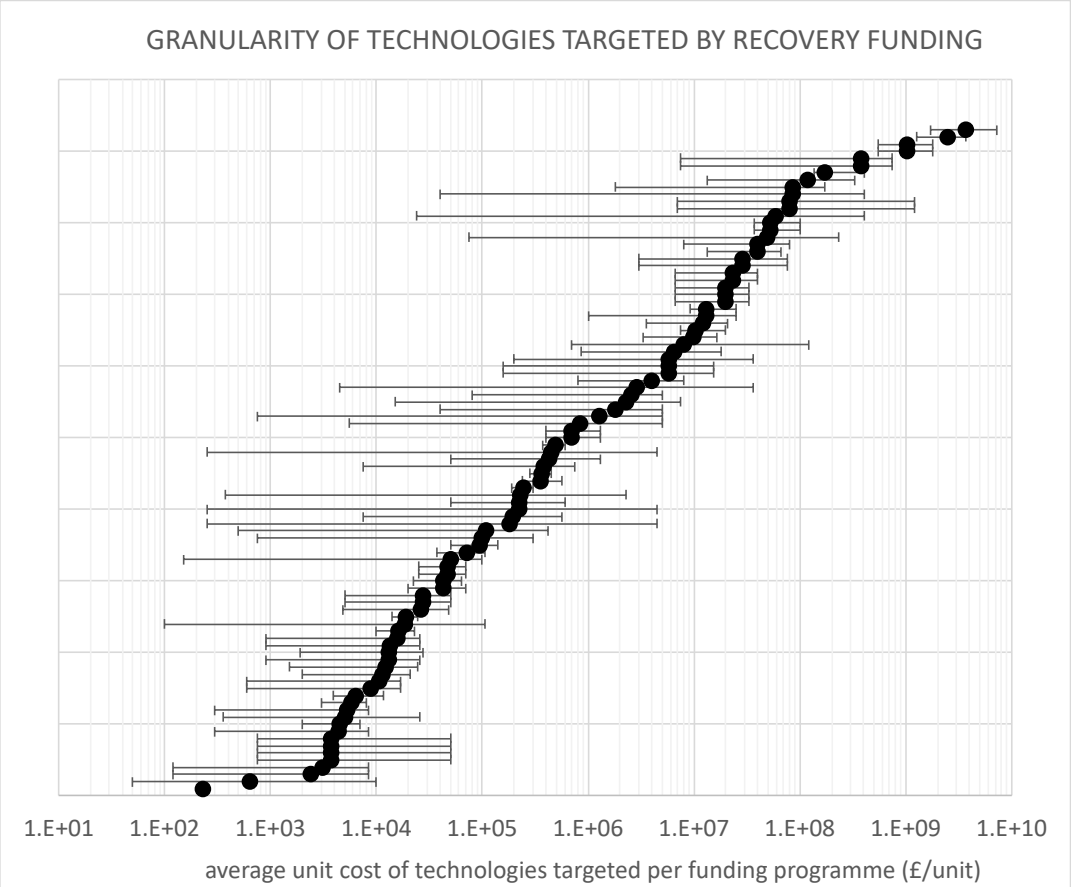
Granularity insights for carbon dioxide removal (CDR)

CDR deployment needs to scale by 4-6 orders of magnitude by 2050 to meet climate targets (>50% annual growth rate)



Source: Smith, Geden, Nemet et al. (2023). The State of Carbon Dioxide Removal - 1st Edition. DOI: 10.17605/OSF.IO/W3B4Z

Technological CDR units are lumpy: BECCS, DAC



habitat restoration
[£450,000/unit]

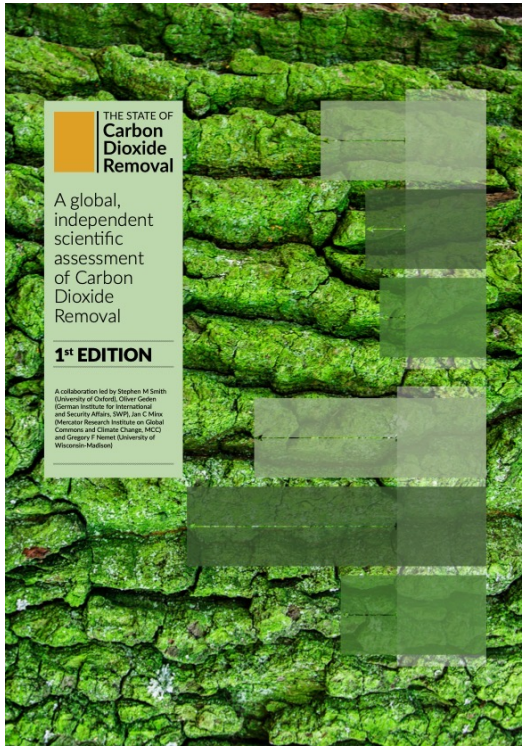
tree planting
[£5000/unit]

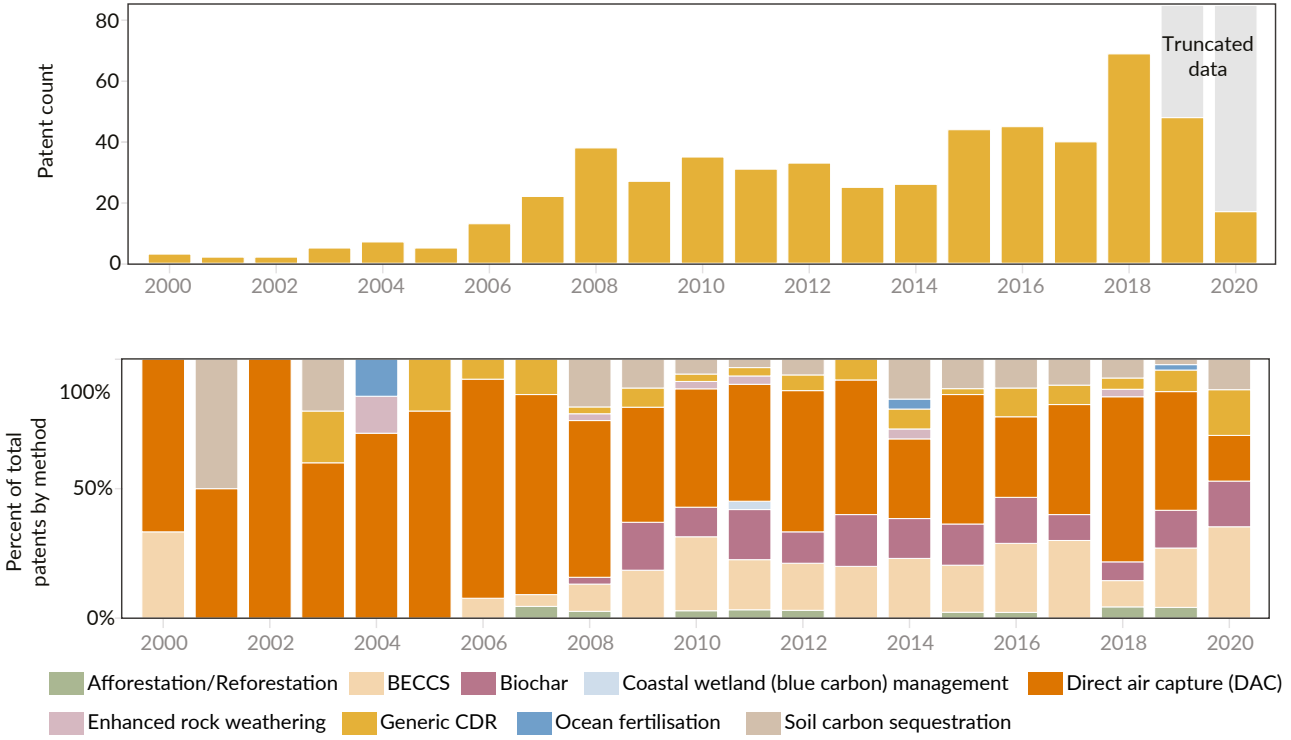
large-scale CCS
[>£1bn/unit]

CO_2 DAC
[>£350m/unit]

'blue' H_2 production with CCS
[>£150m/unit]

CDR innovation portfolios are currently weighted towards lumpy technologies: BECCS, DAC (exception = biochar).





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Granularity insights for carbon dioxide removal (CDR): - conclusions

R&D portfolios *and* deployment funding should be distributed over unit scales:

- land-use CDR outperforms technological CDR on granularity criterion

Rapid cost improvements for lumpy technologies (via learning) are not realistic:

- negative learning observed in flue gas desulphurisation (FGD) = analogy for CCS

System integration matters:

- rapid scale-up of granular CO_2 capture is constrained by need for lumpy CO_2 transport & storage infrastructure

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