Transforming energy demand to meet the 1.5°C target and Sustainable Development Goals without negative emission technologies

Charlie Wilson
International Energy Agency, November 2018

acknowledging: Arnulf Grubler and colleagues at IIASA
overview

- challenging the conventional wisdom on 1.5°C
- why disruptive innovations are important
- why granularity is important
- why energy-service efficiency is important
- how we developed the LED scenario
- energy demand in the LED scenario
- implications of the LED scenario
overview

- challenging the conventional wisdom on 1.5°C
- why disruptive innovations are important
- why granularity is important
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- implications of the LED scenario
Conventional wisdom for meeting the 1.5°C target says ...

**Overshoot** as energy supply technologies scale slowly, but need massive long-term deployment to meet high levels of energy demand.

**Inertia** in policy & technological systems

**Negative emission technologies**
Is the conventional wisdom for meeting the 1.5°C target right?

Problems with conventional wisdom ...

• Negative emission technologies are unproven, risky & conflictual
• Scenarios and modelling are biased towards supply-side solutions
• 1.5°C requires rapid transformation which is inescapably socio-technical
• Potential for the emergence of novelty is under-explored
Is the conventional wisdom for meeting the 1.5°C target right?

Problems with conventional wisdom ...

• Negative emission technologies are unproven, risky & conflictual
• Scenarios and modelling are biased towards supply-side solutions
• 1.5°C requires rapid transformation which is inescapably socio-technical
• Potential for the emergence of novelty is under-explored

In response ...

• ‘Low Energy Demand’ (LED) scenario
• Explores rapid transformation in energy services through social, organisational, and technological innovation
• Allows for rising activity levels to meet decent living standards
• Downsizing energy use enables feasible supply-side decarbonisation
Is the conventional wisdom for meeting the 1.5°C target right?

**Overshoot** as energy supply technologies scale slowly, but need massive long-term deployment to meet high levels of energy demand.

**Inertia** in policy & technological systems.

**Negative emission technologies**

**Rapid Transformation** in energy services and efficiency, with rising activity levels.

**Distributed energy supply** scales rapidly in a down-sized energy system.

Emissions vs. Time
Low Energy Demand (LED) scenario: disruptive consumer innovation, granularity, energy-service transformation + *standards*

**Rapid Transformation**
in energy services and efficiency, with rising activity levels

**Distributed energy supply**
scales rapidly in a down-sized energy system
Low Energy Demand (LED) scenario: disruptive consumer innovation, granularity, energy-service transformation + standards
Low Energy Demand (LED) scenario: disruptive consumer innovation, granularity, energy-service transformation + *standards*

LED scenario is based off SSP2 assumptions

Source: IPCC (2018) Special Report on Global Warming of 1.5°C. Figure SPM 3b.
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## Technology Lifecycle

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<th>Applied Development</th>
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<th>Market Formation</th>
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\(^{a}\) Wilson & Grubler (2014)  
\(^{b}\) EC (2017)  
\(^{c}\) Kramer & Haigh (2009)  
\(^{d}\) Bento & Wilson (2016)

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### Emergence of Novelty?

### Energy-Service Transformation?
## Technology Lifecycle

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- **Technology Lifecycle a**
- **TRL<sup>b</sup>**
- **Basic Research**
- **Applied Development**
- **Demonstration**
- **Market Formation**
- **Rapid Diffusion**
- **Maturity**

### 1.5°C Mitigation Options in Global IAMs

- **bioCCS**
- **fossilCCS**
- **solar power**
- **wind power**
- **nuclear power**
- **public transport**
- **electric vehicles**
- **building insulation**

### Sources:
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### Energy Technologies

- **bioCCS**
- **fossilCCS**
- **solar power**
- **wind power**
- **nuclear power**
- **public transport**
- **electric vehicles**
- **building insulation**

### Emergence of Novelty?

### Energy-Service Transformation?
Disruptive innovations offer novel attributes to end users ... and can rapidly change markets

*Sustaining innovations* -> improve currently valued attributes

- power
- speed
- storage
- low cost per MB
- portability
- versatility
- accessibility (coding)
- low cost per unit

*Disruptive innovations* -> offer novel attributes, create new value
energy X digital X users

Is disruptive innovation relevant for low-carbon transitions?

Dedicated section in: IPCC (2018) Special Report on Global Warming of 1.5oC
Chapter 4: Strengthening & implementing the global response

potentially disruptive consumer innovations

e-bikes  ‘taxi-bus’  ride-share  car-share  bike-share  MaaS  VR & tele-presence

SILCI project: silci.org
potentially disruptive consumer innovations

e-bikes  ‘taxi.bus’  ride-share  car-share  bike-share  MaaS  VR & tele-presence

P2P goods  P2P homes  internet of things  smart appliances  pre-fab retrofits  smart homes  heat pumps

SILCI project: silci.org
potentially **disruptive** consumer innovations

e-bikes  ‘taxi-bus’  ride-share  car-share  bike-share  MaaS  VR & tele-presence

P2P goods  P2P homes  internet of things  smart appliances  pre-fab retrofits  smart homes  heat pumps

PV + storage  P2P electricity  vehicle-to-grid  disag. feedback  time-of-use pricing  demand response  energy service co.s

VR & tele-presence

P2P goods  P2P homes  internet of things  smart appliances  pre-fab retrofits  smart homes  heat pumps

PV + storage  P2P electricity  vehicle-to-grid  disag. feedback  time-of-use pricing  demand response  energy service co.s
‘mega-trend’ (1) from ownership to **usership**

- e-bikes
- ‘taxi-bus’
- ride-share
- car-share
- bike-share
- MaaS
- VR & tele-presence
- P2P goods
- P2P homes
- internet of things
- smart appliances
- pre-fab retrofits
- smart homes
- heat pumps
- PV + storage
- P2P electricity
- vehicle-to-grid
- disaggregation
- time-of-use pricing
- demand response
- energy service co.s
‘mega-trend’ (2) sharing economy, including P2P

- e-bikes
- ‘taxi-bus’
- ride-share
- car-share
- bike-share
- MaaS
- VR & telepresence
- P2P goods
- P2P homes
- internet of things
- smart appliances
- pre-fab retrofits
- smart homes
- heat pumps
- PV + storage
- P2P electricity
- vehicle-to-grid
- disaggregation feedback
- time-of-use pricing
- demand response
- energy service co.s
‘mega-trend’ (3) from atomised to connected

- e-bikes
- ‘taxi-bus’
- ride-share
- car-share
- bike-share
- MaaS
- VR & telepresence
- P2P goods
- P2P homes
- internet of things
- smart appliances
- pre-fab retrofits
- smart homes
- heat pumps
- PV + storage
- P2P electricity
- vehicle-to-grid
- disaggregation feedback
- time-of-use pricing
- demand response
- energy service co.s
currently *commercial*, niche, but growing rapidly
factored into **LED scenario** (1st order estimates)
emergence of novelty?

energy-service transformation?

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- **1.5°C mitigation options in global IAMs**
  - bioCCS
  - fossilCCS
  - solar power
  - wind power
  - nuclear power
  - public transport
  - electric vehicles
  - building insulation

- **1.5°C carbon mitigation options in global IAMs**
  - ≈20 years
  - ≈30 years

- **1.5°C low-carbon innovations**
  - mobility-as-a-service
  - EVs & vehicle-to-grid
  - smart home technology
  - P2P goods, P2P homes
  - pre-fab low-energy retrofits
  - PV, storage

- **1.5°C consumer-facing innovations**
  - if strong consumer pull

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overview

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- why disruptive innovations are important
- why granularity is important
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- how we developed the LED scenario
- energy demand in the LED scenario
- implications of the LED scenario
‘granular’
small unit size
low unit cost
modular
replication

‘lumpy’
large unit size
high unit cost
indivisible
up-scaling
Granular energy technologies diffuse faster (+ are lower risk, + more equitably distributed)

35% of variance in $\Delta t$ is explained by investment size per unit

Wilson, Grubler, Bento et al. (forthcoming). “Small is Better: The Benefits of Granularity in Energy Technologies”
Granular energy technologies have higher learning rates (controlling for up-scaling)

Learning rates per doubling of cumulative # of units controlling for unit economies of scale (exc. 2 outliers)

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Energy-related mitigation strategies from an *energy service* perspective
Energy-related mitigation strategies from an *energy service* perspective

**SUPPLY**
- decarbonise energy supply
- improve conversion efficiency
  - + reduce distribution losses

**END-USE**
- change the form or ‘quality’ of the service
- useful service
- mobility
- improve conversion efficiency

*Mobility*
Energy-related mitigation strategies from an *energy service* perspective

**SUPPLY**
- decarbonise energy supply
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- + reduce distribution losses

**END-USE**
- change the form or ‘quality’ of the service
- improve conversion efficiency
- improve ‘service’ efficiency

*useful service*
mobility

if urban mobility was provided by on-demand shared vehicles, what % of today’s vehicle fleet would be needed?
mobility

service efficiency
  e.g., increase vehicle occupancy

conversion efficiency
  e.g., improve fuel efficiency
**mobility**

**service efficiency**
- e.g., increase vehicle occupancy

**conversion efficiency**
- e.g., improve fuel efficiency

- **technological innovation**
- **social or institutional innovation**
- **organisational or business model innovation**
- **behavioural innovation**
consumer goods

if smart phone functionality displaced domestic devices and appliances, what % of today’s electricity would be needed to power consumer goods?
consumer goods

service efficiency
e.g., device convergence

e.g., improve device efficiency

conversion efficiency

Power consumption

449 Watt

72 Watt

Stand-by
consumer goods

service efficiency
  e.g., device convergence

conversion efficiency
  e.g., improve device efficiency

- technological innovation
- organisational or business model innovation
- social or institutional innovation
- behavioural innovation
heating & cooling buildings

who occupies the second largest amount of office space in London?
heating & cooling buildings

service efficiency
e.g., diversify use to increase occupancy

conversion efficiency
e.g., improve energy efficiency
heating & cooling buildings

service efficiency

e.g., diversify use to increase occupancy

conversion efficiency

e.g., improve energy efficiency

---

Ask WeWork what makes it so special and they will say it is about so much more than office space. It is about the “We Generation” – a largely Millennial workforce who demand more from their work than just a job ... they value experiences over material goods, crave a sense of community and fulfilment, and want to be part of something greater than themselves. [WIRED, Jun 2018]
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Low Energy Demand (LED) scenario: disruptive consumer innovation, granularity, energy-service transformation + standards

Rapid Transformation in energy services and efficiency, with rising activity levels

Distributed energy supply scales rapidly in a down-sized energy system
A scenario is a possible future ... based on clear, consistent & coherent assumptions about the drivers of future change

‘performative force’
A scenario is a possible future ... based on clear, consistent & coherent assumptions about the drivers of future change

‘performative force’

Note: any scenario in which global warming is limited to 1.5°C is strongly normative
scenario
narrative
drivers of change
scenario narrative

drivers of change

bottom-up quantification of activity and energy intensity (‘off model’)
downstream ... then upstream

PROCESS

METHOD & TOOLS

thermal comfort

consumer goods

mobility

food

commercial buildings

industry & manufacturing

freight transport
scenario narrative

drivers of change

downstream ... then upstream

bottom-up quantification of activity and energy intensity ('off model')

integrated modelling of system consequences

energy supply & land-use

thermal comfort

commercial buildings

consumer goods

industry & manufacturing

mobility

freight transport

food

MESSAGE (energy-system model)

GLOBIOM (land-use model)

PROCESS

METHOD & TOOLS
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energy supply & land-use

climate & health

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thermal comfort

consumer goods

mobility

food

commercial buildings

industry & manufacturing

freight transport

MESSAGE (energy-system model)

GLOBIOM (land-use model)

GAINS (air pollution)

MAGICC (climate)
quality of life
urbanisation
end-user roles

LED scenario
quality of life, urbanisation, end-user roles, information innovation, LED scenario
quality of life
urbanisation
novel energy services
end-user roles
information innovation
quality of life  
urbanisation  
novel energy services  
end-user roles  
information innovation
quality of life
urbanisation
novel energy services
information innovation
decentralised service provision
deep-end-user roles
rapid transformation
granularity
don-use value from services
digitalisation of daily life
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changes from 2020 to 2050

**increase in activity**
- factor 2 increase in Global South (7,600 p-km)

**reduction in energy intensity**
- factor 3 reduction (engine-to-wheel) from electrification
  + shared & responsive modes
  + increase vehicle occupancy by 25% and daily usage by 75%
  + global vehicle fleet halves!
thermal comfort

changes from 2020 to 2050

increase in activity
- converge on 30m²/capita

reduction in energy intensity
- Global North: double retrofit rate to 3%
- Global South: new build to Passivhaus standards

+ consumer preference for multi-functionality (e.g. heat pumps, fuel cells)

+ mixed use & flexible use building design
changes from 2020 to 2050

**increase in activity**
- factor 3 increase in Global South (~24 devices/capita)

**reduction in energy intensity**
- improves 15% per device on average (~82 kWh/device)
- improves >70% in lighting (LEDs!)

+ device convergence (multi-functionality)
+ ownership to 'usership'
**scenario narrative**  
**drivers of change**  
bottom-up quantification of activity and energy intensity ('off model')  
downstream ... then upstream  
**integrated modelling of system consequences**  
energy supply & land-use  
climate & health  
across all end-use services to 2050

**increase in activity**  
- more demand for useful services (esp. Global South)

AND

**reductions in energy intensity**  
- improved conversion efficiency  
- avoided losses (passive systems)

- new forms of service provision  
- improved service efficiency
By 2050, more services are provided with less energy (columns show Δ from 2020 to 2050)
By 2050, **more services** are provided with **less energy** (columns show Δ from 2020 to 2050)
scenario narrative

drivers of change

bottom-up quantification of activity and energy intensity ('off model')
downstream ... then upstream

PROCESS

METHOD & TOOLS
deeply quantified activity and energy intensity ('off model')
donstream ... then upstream

thermal comfort

consumer goods

mobility

food

commercial buildings
industry & manufacturing
freight transport

food

mobility

consumer goods

thermal comfort

commercial buildings
industry & manufacturing
freight transport
By 2050, more services are provided with less energy ... with knock-on effects upstream

![Graphs showing changes in energy demand and final energy efficiency across different sectors](image-url)
LED is the lowest global energy demand scenario ever published (we think)
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Energy end-use in LED is rapidly electrified, with renewables the dominant resource
Down-sizing the energy system enables faster and more feasible decarbonisation

Compared to other $\leq 2^\circ$C scenarios, renewables in LED have

<table>
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<tr>
<th>higher <em>relative</em> market shares:</th>
<th>lower <em>absolute</em> growth rates:</th>
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<td>8% (by 2020)</td>
<td>20-50% historically</td>
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<tr>
<td>32% (by 2030)</td>
<td>15% (2020 to 2030)</td>
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<td>60% (by 2050)</td>
<td>5-10% (2040 to 2050)</td>
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LED uses SDG12 (responsible consumption and production) as entry point for addressing other SDGs. 

e.g., LED avoids 1.4m premature deaths per year through reduced air pollution [GAINS model]
Conclusions & implications from LED scenario analysis

• Limiting warming to 1.5°C is just about conceivable without CCS and negative emission technologies

• Importance of accelerated transformation in energy services
  • social + organisational innovation as well as technological
  • e.g., ‘usership’, granularity, sharing economy, digitalisation, diverse end user roles, economies of scope

• Policy implications:
  • from mega-projects & energy supply to empowering energy users
  • from carbon pricing to standards, ‘scripted’ innovation, and open regulatory environments

• Implications for us:
  • countless opportunities to enjoy energy services for dramatically less energy consumption
Transforming energy demand to meet the 1.5°C target and Sustainable Development Goals without negative emission technologies

Charlie Wilson
IEA, November 2018

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