Imperial College London

UKERC
UK Energy Research Centre
Researching pathways to a low carbon future

Innovation in energy: Theory, timescales and the role of policy

Dr Robert Gross
Director of the Centre for Energy Policy and Technology
Imperial College London

Presentation overview

1. The role and importance of innovation
2. Academic theory on innovation
3. How long does innovation take?
4. What is different about energy innovation?
5. The role of policy
6. Conclusions

UKERC

Why is innovation important?

Low carbon technologies often start out as more expensive and less desirable than conventional

- Supply side: wind power, solar, CCS
- Demand side: electric cars, early CFLS, heat pumps

Innovation can drive cost reductions and improve performance

- Over time, low carbon/high efficient options become first best
- Hybrid cars, LED lights, Advanced glazing and insulation

Innovation can create options, possibilities for system change

- Smart meters and active demand side response
- Phase change materials and heat storage

Thus innovation has the potential to transform responses to climate change

UKERC

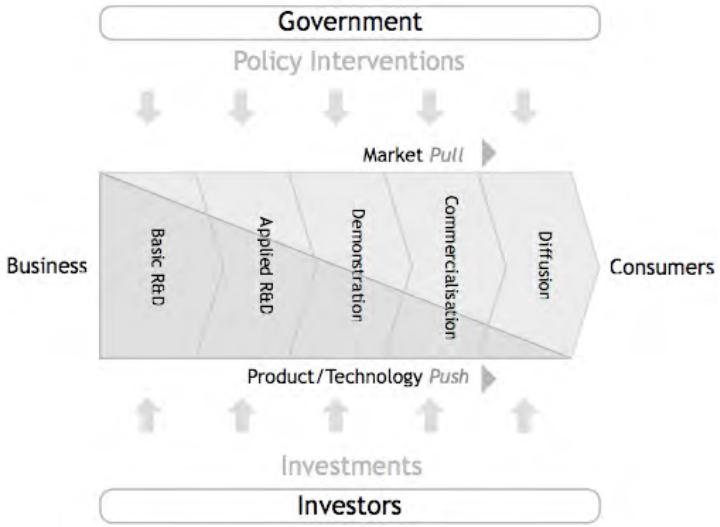
Innovation theory overview

- Early linear model (1930s, Schumpeter)
  - basic R&D to applied R&D to development & diffusion – increase innovation via technology push
- 1950/60s: Induced innovation
  - demand more important for stimulating innovation – "demand pull"
- Emergence of three important approaches:
  - Induced innovation: changes in input prices drive direction of technical change
  - Evolutionary and path dependency models: past decisions constrain innovation
  - Key concepts: uncertainty, bounded rationality, increasing returns to adoption
- Uncertainty & bounded rationality: tend to favour incremental innovation
- Increasing returns: the more a technology/institution becomes established, the more it is likely to be further adopted
  - scale and learning effects deliver cost reductions and incremental improvements

UKERC

Innovation theory overview (continued)

- Late 20th century: evolving systems perspective
  - emphasises: knowledge flows; future expectations; regulatory risk; institutional structures
  - multiple feedbacks: demand; supply; and the 'regime'
- perspectives include
  - national innovation systems
  - technological innovation systems
- Particular focus on transition dynamics:
  - incremental, radical, and disruptive innovation
  - importance of niche management to nurture innovation



Emphasis on policy role in innovation chain to correct for systems failure

UKERC

The importance of timescales

- Innovation IS NOT JUST R&D and invention of new options
- Key concern – time for technology to emerge from fundamental research, go through demonstration and early stage deployment and diffuse into the market place

- For new low carbon technologies to play a substantial role then it will be necessary for them to be proven, available and **deployed at a scale that is sufficient for them to make a material impact**

- Debate about the affordability of large scale deployment subsidies and the role of governments in deciding which technologies to support

- Some argue that large scale support for deployment should be substantially reduced and support for R&D scaled up

UKERC

UKERC has therefore undertaken a review of innovation timescales

- Technology and Policy Assessment Review: Primary function is to inform policy and address key controversies in the energy policy field
- Systematic reviews of the evidence base, to provide clear, accessible analysis on the current state of knowledge
- Part of UKERC since the centre was established in 2004 and now in its third phase, which started in 2014
- Recent increasing focus on shorter projects, based on Rapid Evidence Assessment (REA) techniques

UKERC

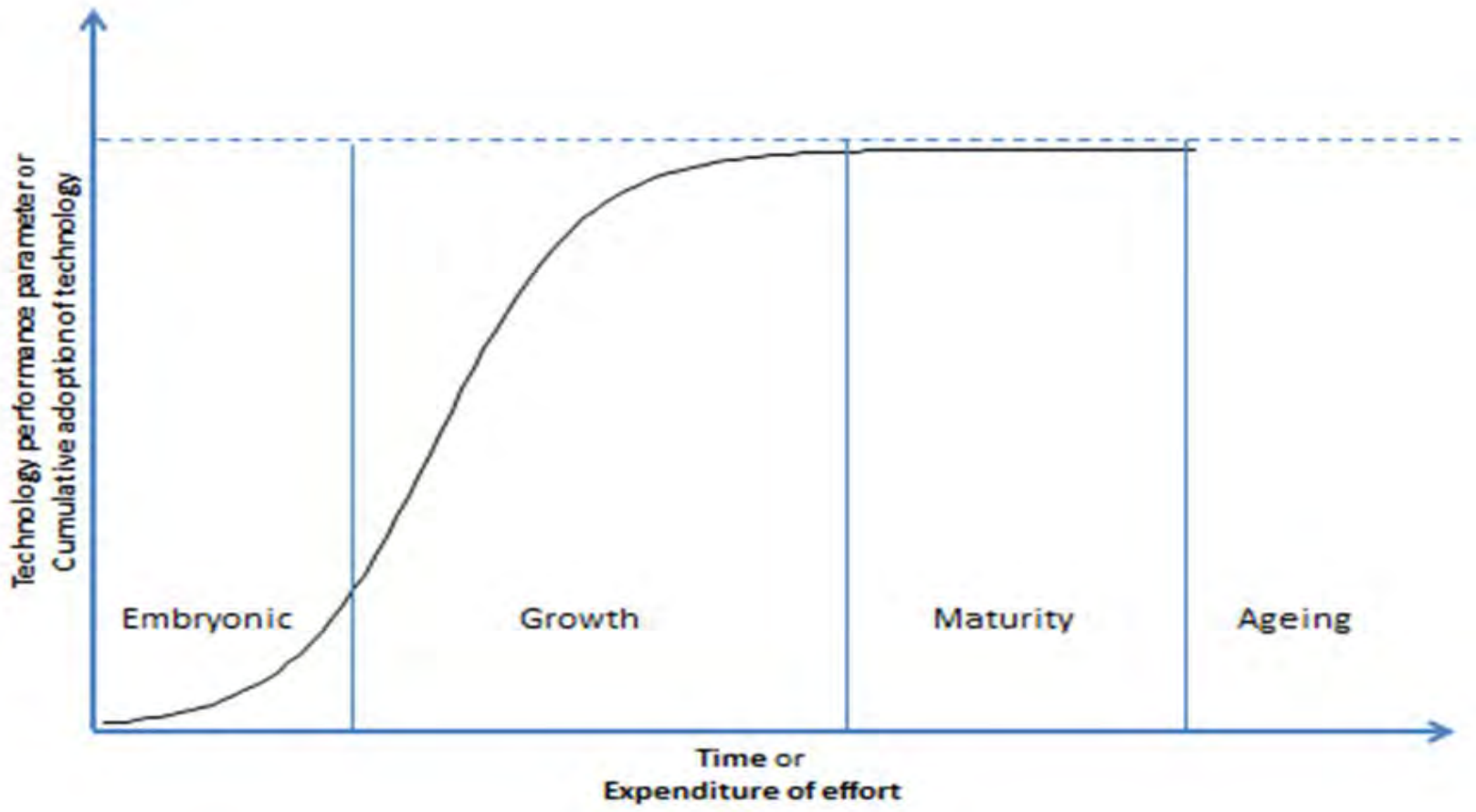
Research question and approach

"What is the evidence for the time new technological innovations take to reach commercial maturity?"

- A Rapid Evidence Assessment (REA) – a short but systematic assessment
- Initial scope not constrained to energy technologies
- Examine the existing literature around innovation timescales
- Summarise the range of time technologies have taken to develop through the technological innovation system
- 14 innovations reviewed including five energy-specific case studies

UKERC

The innovation 'journey' – technology S-curve



Source: Taylor & Taylor (2012)

UKERC

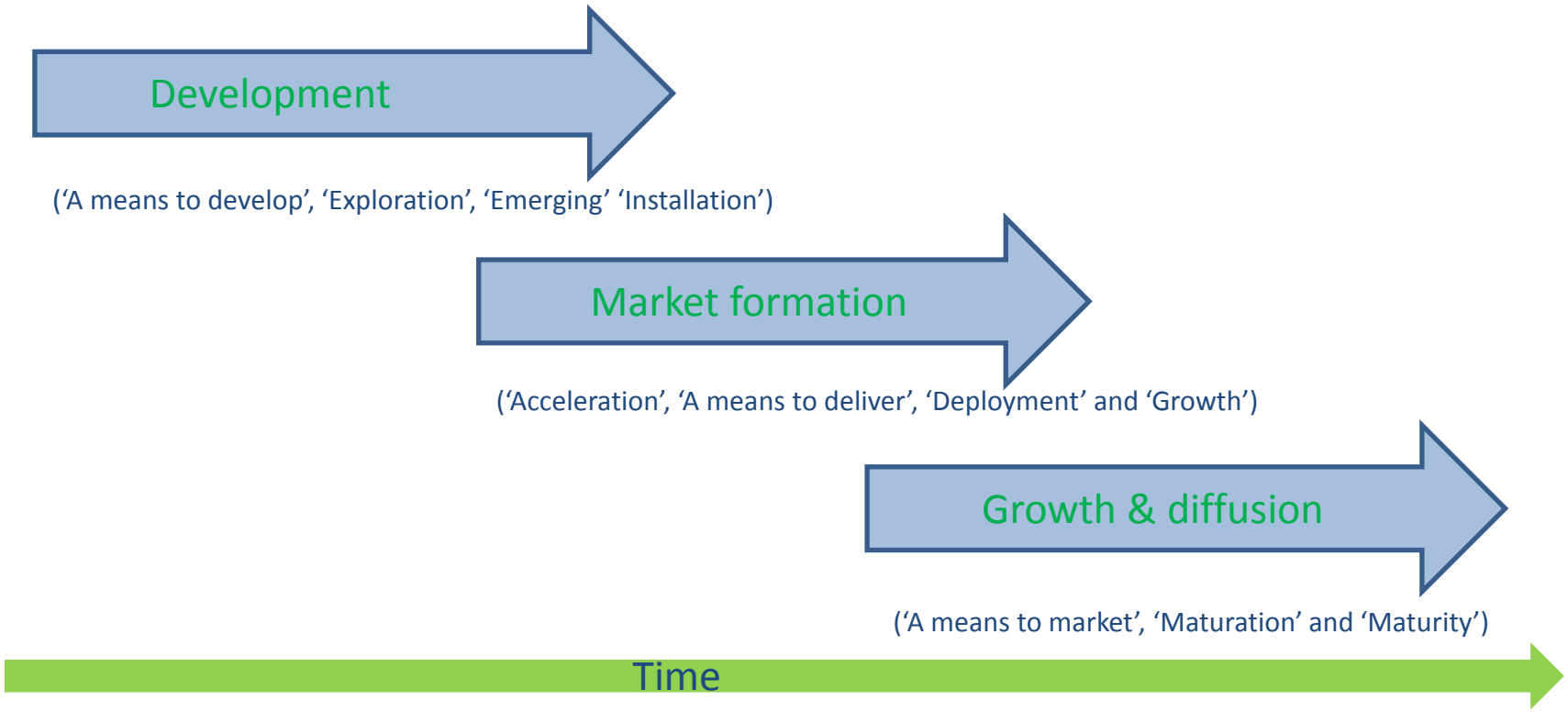
Search terms and keywords

Initial search term categories		Subsequent search term filters
Innovation	**Temporal**	**Innovative technology or product**
Innovation	Time	Cars / automobiles
Research	Life	"Catalytic converter"
Mass market	Cycle	"Lithium ion" AND "rechargeable batteries"
"Market saturation"	Rate	"Lithium ion" AND "electric vehicles" AND batteries
Commercialisation	Speed	Television / "Cathode Ray Tube TV" / "CRT TV"/ "Liquid Crystal Display TV" / "LCD TV"
Deployment	History	"Automatic Teller Machine" / ATM / "cash cards"
Diffusion		"Videocassette recorder" / VCR
Uptake		"Mobile phone"
"Innovation life cycle"		"Compact fluorescent light bulbs" / CFLs
"Technology life cycle"		"LED light bulbs" / "LED lamps"
Technology		"Combined cycle gas turbines" / CCGT
"Product development"		"Wind electricity"
		"Nuclear power"
		"Solar photovoltaics" / "solar PV"

- Databases used:
  Science Direct; World Cat
- Studies with a global scope included + those which focused in particular on OECD or EU (including the UK) countries, USA or Japan.
- Results identified suitable innovative product or technologies for review, extracting details on (i) the timescales for specific innovation stages presented and; (ii) the geographic region (if not global).

UKERC

Definitions and terminology differ

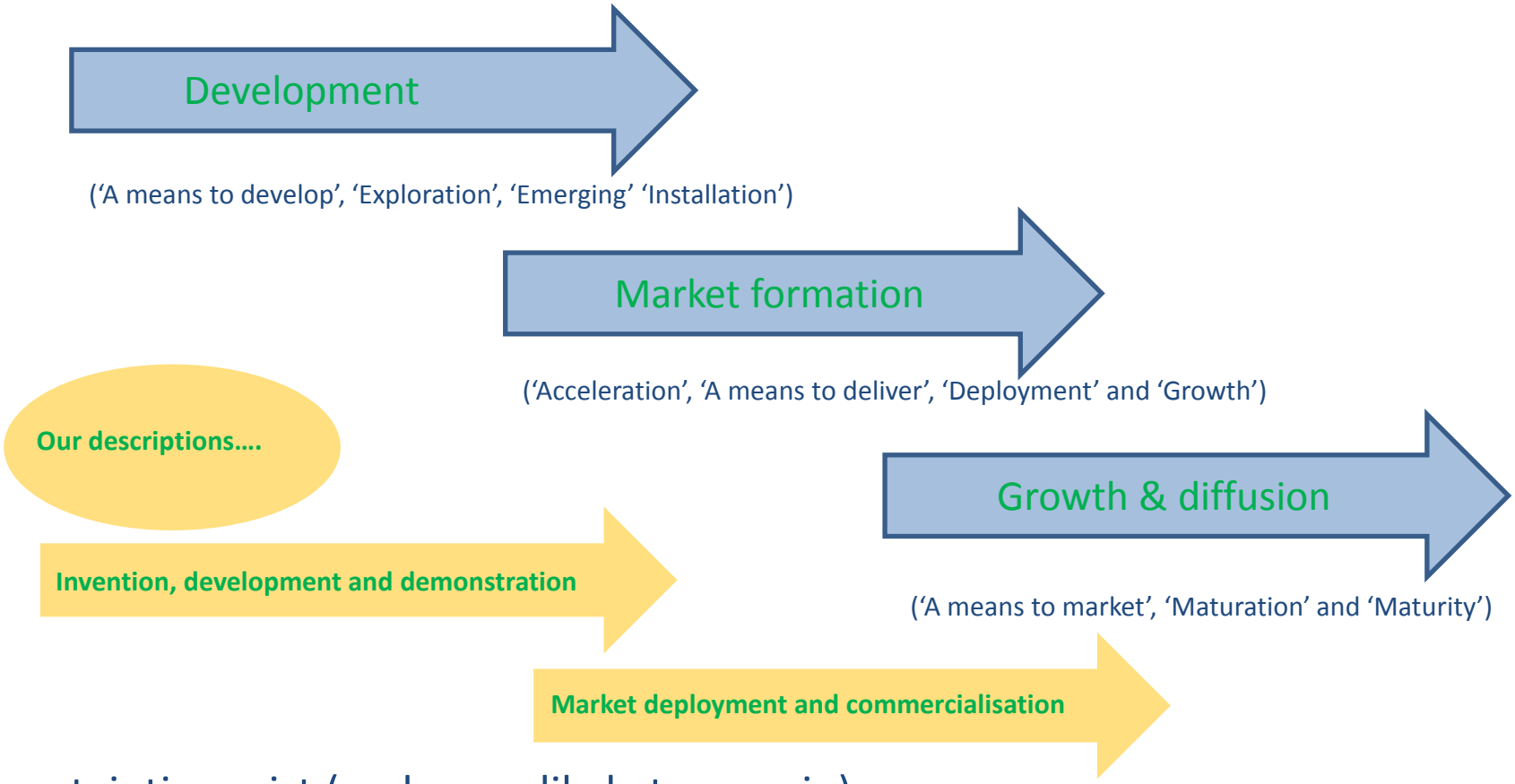


Uncertainties exist (and seem likely to remain) over:

- The number and definition of each activity
- When a technology moves from one activity to another

UKERC

Definitions and terminology differ

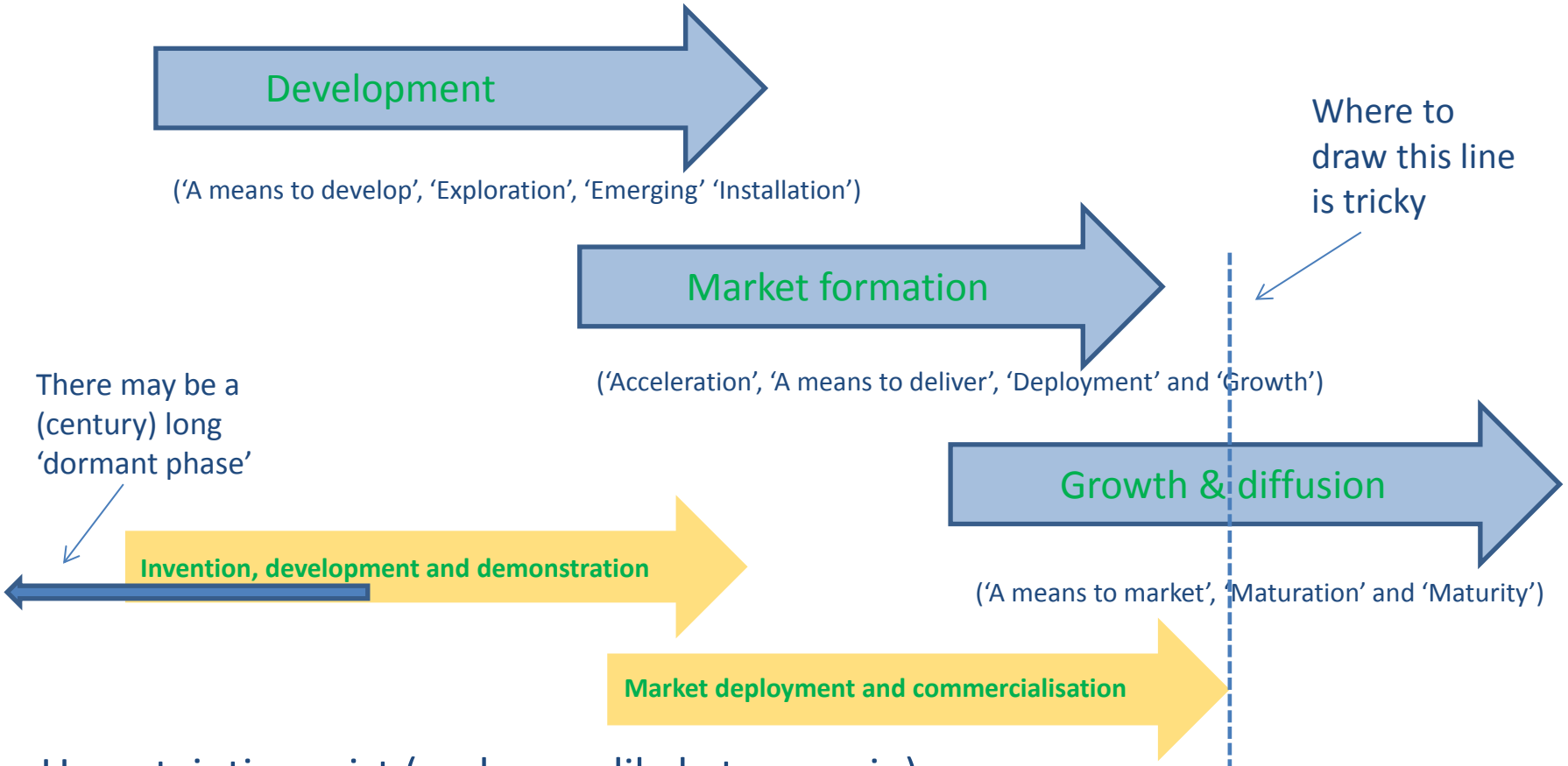


Uncertainties exist (and seem likely to remain) over:

- The number and definition of each activity
- When a technology moves from one activity to another

UKERC

It isn't straightforward…



Uncertainties exist (and seem likely to remain) over:

- The number and definition of each activity
- When a technology moves from one activity to another

UKERC

Defining invention, deployment and commercialisation

- Point of invention –first year in which a product or technological application was conceived
  - e.g. the first silicon solar cell rather than the discovery of the photovoltaic effect
  - For some products with extended timeline for the concepts (e.g windmills) we use first modern application/device
- Market deployment and commercialisation phase – market introduction
  - When product first entered the market or became commercially available
  - First generation unit connected to the grid
- Widespread commercialisation – slightly more complex…

UKERC

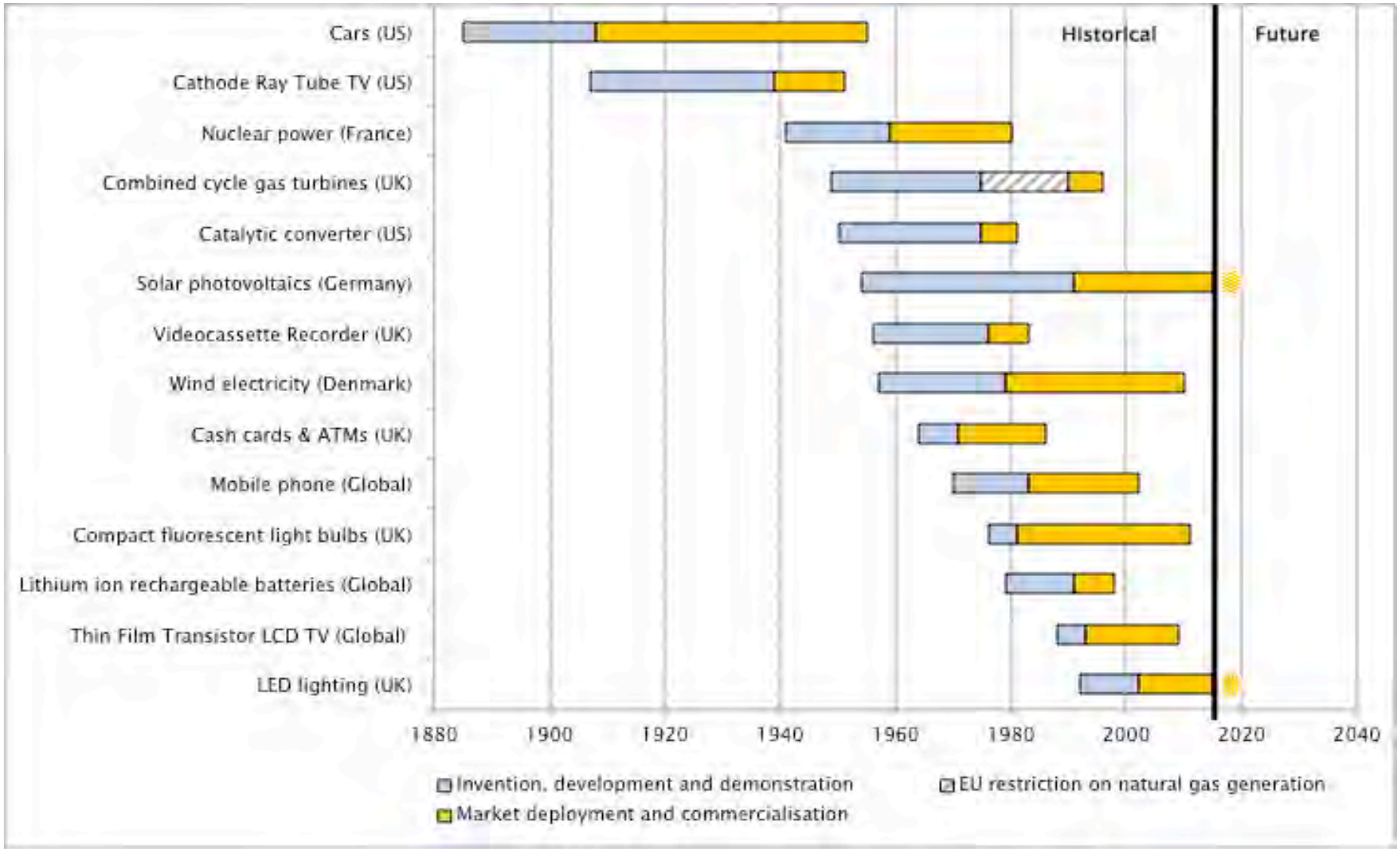
Widespread commercialisation

Innovation category	How widespread commercialisation is defined in this study	Geographies applicable
Novel consumer and energy end use products	When 20% of maximum cumulative units was reached[1]	UK, US
Replacement consumer products	When the market share of the replacement innovation overtook that of the incumbent / rival products and became the dominant market share (measured either by annual sales or cumulative units)	UK, US, Global
Electricity generation technologies	20% share of electricity production.	UK, Denmark, France, Germany

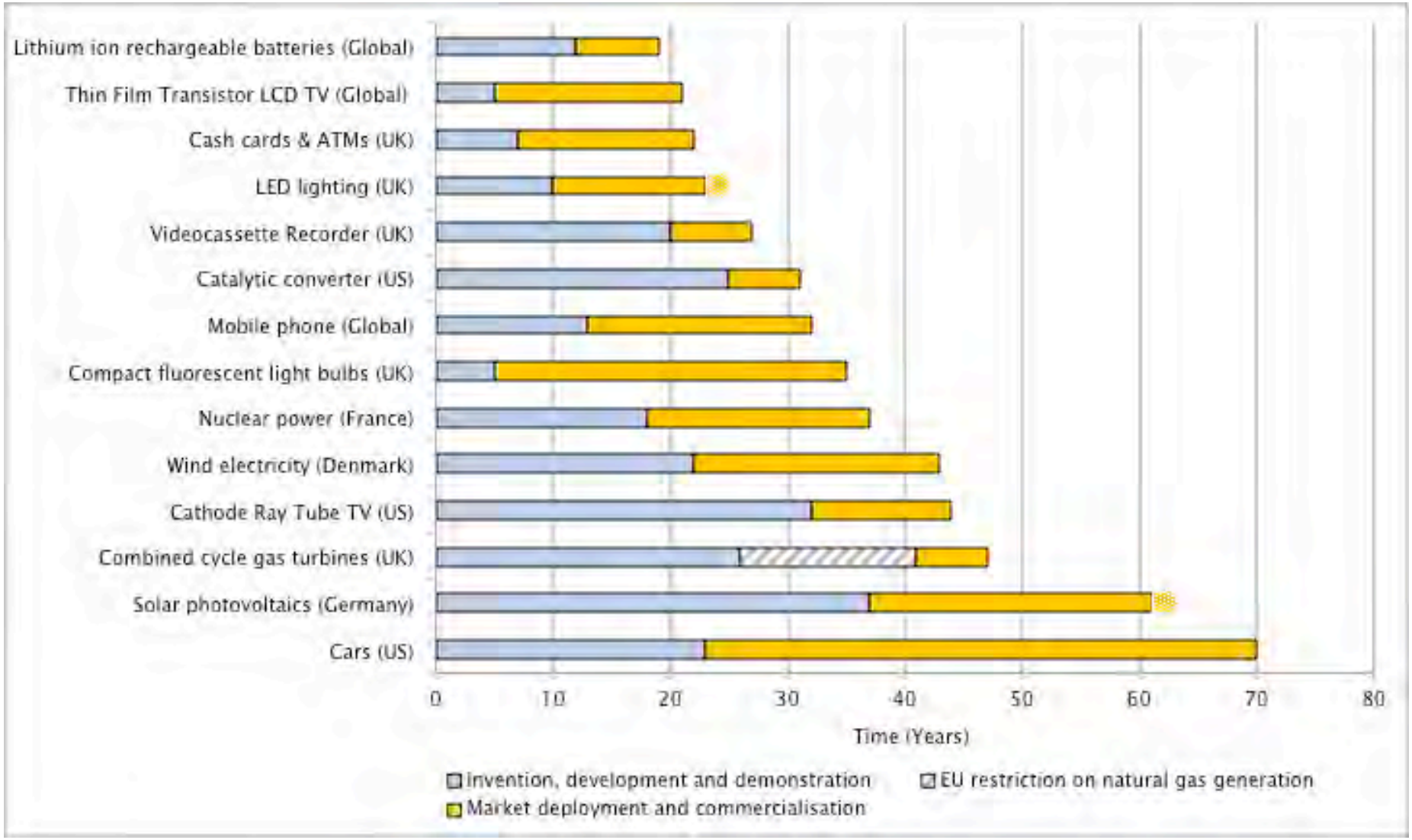
[1] The 20% of maximum cumulative units definition is similar to that applied to consumer and financial products/services in a study by Wonglimpiyarat (2005, p.868), who refers to a 'means to market' phase which begins after: '…the distribution capabilities (distribution channels) are sufficient to access 20% of the target population of users for the innovation'. In the case of the VCR, for example, the 'means to market' stage began when 'the production capacity to supply 20% potential worldwide demand of VCRs was achieved within 2 years' (Wonglimpiyarat, 2005, p. 878).

UKERC

Timescales summary (dates)



Timescales summary (duration)

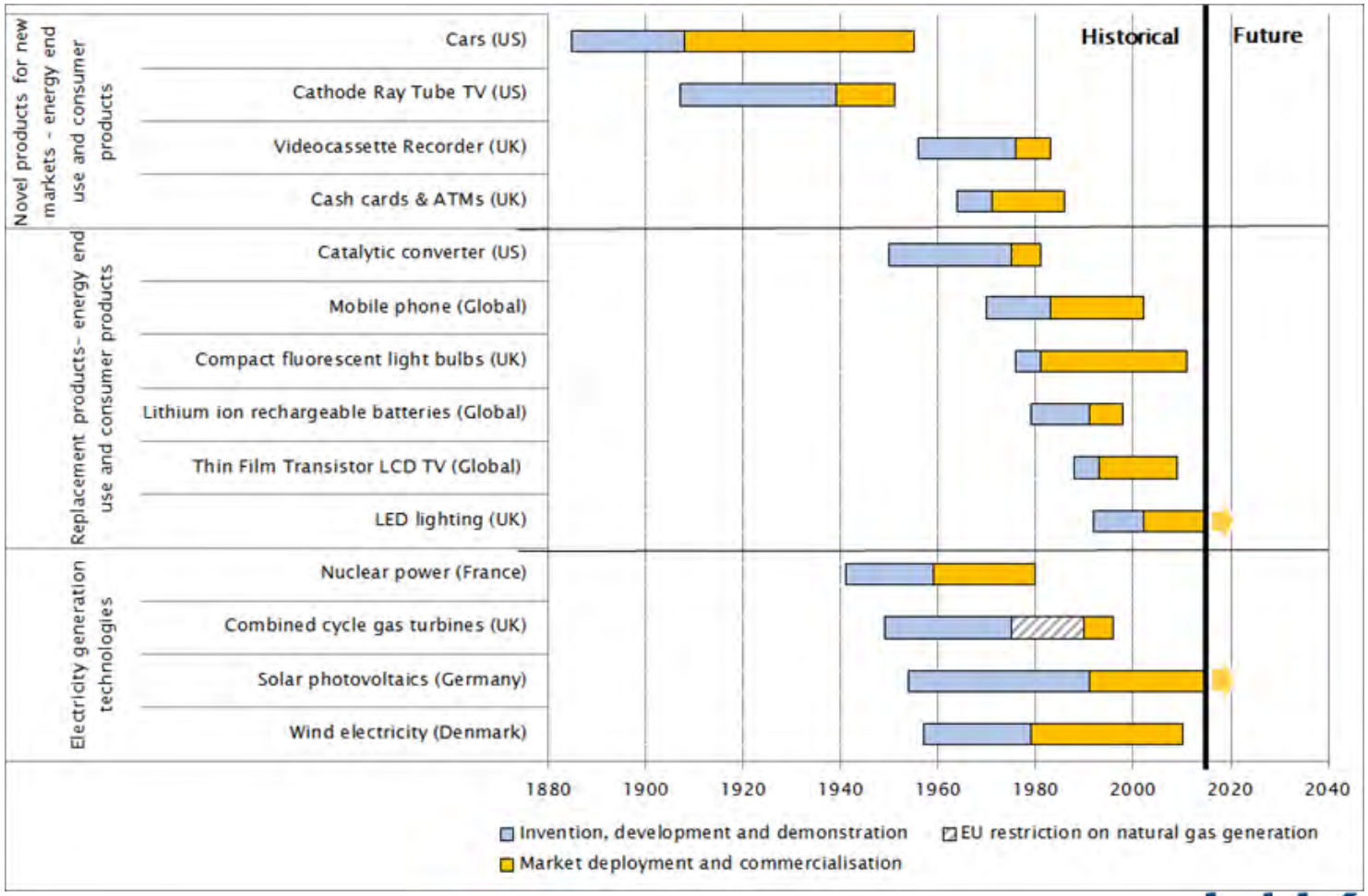


Mean duration of innovation (median durations indicated in brackets)

Innovation category	Invention, development and demonstration	Market deployment and commercialisation	Invention to commercialisation (Total)
Novel consumer products – energy end use	20.5 *(21.5)*	20.3 *(13.5)*	40.8 (*35.5)*
Replacement consumer products – energy end use	11.7 *(11.0)*	15.2 *(14.5)*	26.8 *(27.0)*
Energy end use and consumer products *(comprise both novel and replacement products)*	15.2 *(12.5)*	17.2 *(14.0)*	32.4 *(29.0)*
Electricity generation technologies	25.8 *(24.0)*	24.3 *(22.5)*	50.0 *(50.0)*

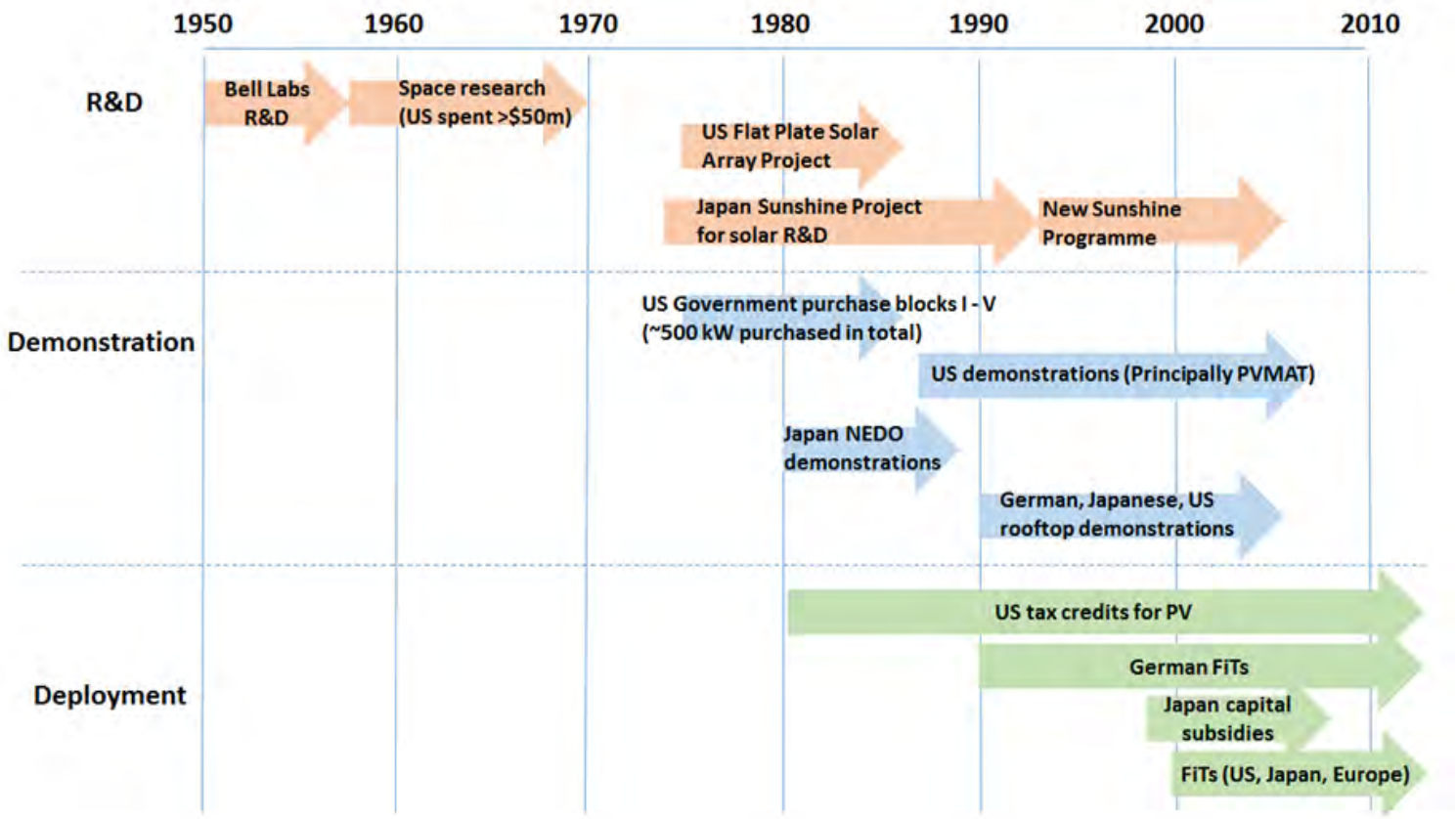
UKERC

Timescales summary (categories)



UKERC

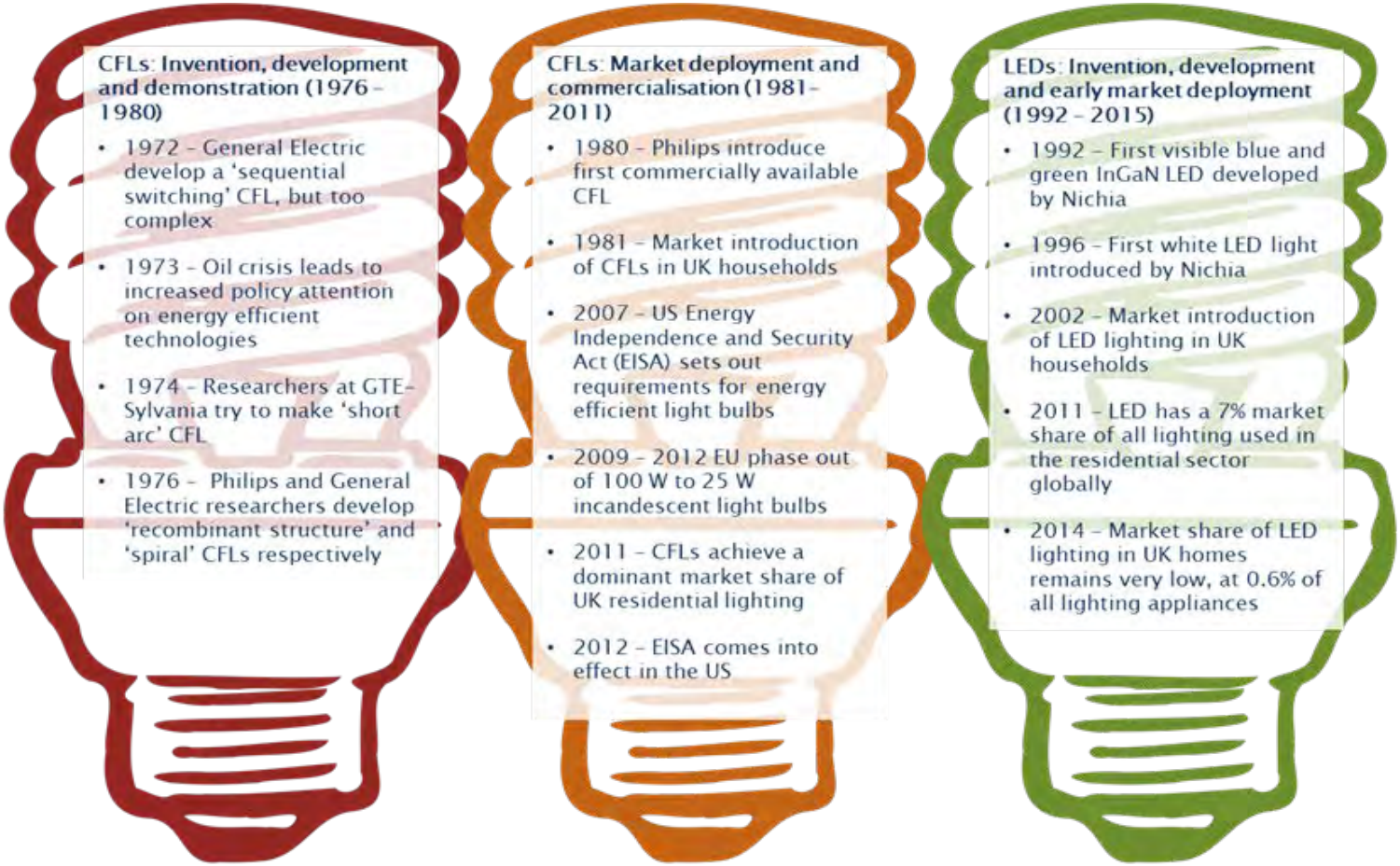
Example: PV



Key policies driving solar PV innovation and cost reductions (Gambhir et al., 2014)

UKERC

Example: CFLs and LED lights



UKERC

General observations

- Wide range of time needed to achieve widespread commercialisation –around two decades to more than half a century
  - Average (and typical) is **three to four decades**
  - **Energy supply technologies took over four decades**
  - **Energy demand/storage quicker** – Lithium ion batteries for small consumer products our quickest entirely new product
- Some evidence of innovation speed increasing through time
- Some evidence that incumbent infrastructure affects pace
- Some evidence of spillover from earlier products or military / space research and development
- Policy interventions at several key junctures: post war nuclear; oil crisis nuclear, EE, RE; emerging climate changes concerns
- Some technologies not yet at full commercial stage

UKERC

Conclusions

- Focusing climate policy on 'breakthrough' technologies is high risk and may take too long
- R&D is important but should target both new technologies and improving existing ones
- Research led policy could focus on end use/consumer products that can commercialise more quickly
- Additional research to better characterise timelines for diffusion could reality check modelling and inform policy
- Sustained support/regulation may be needed for several decades before energy efficient/low carbon options become 'the norm' – existing policies still needed/essential:
  - Energy efficiency policy focus on standards, regulation and consumer adoption
  - Energy supply (especially renewables) policy on market creation
  - Policies also needed on networks and storage

UKERC