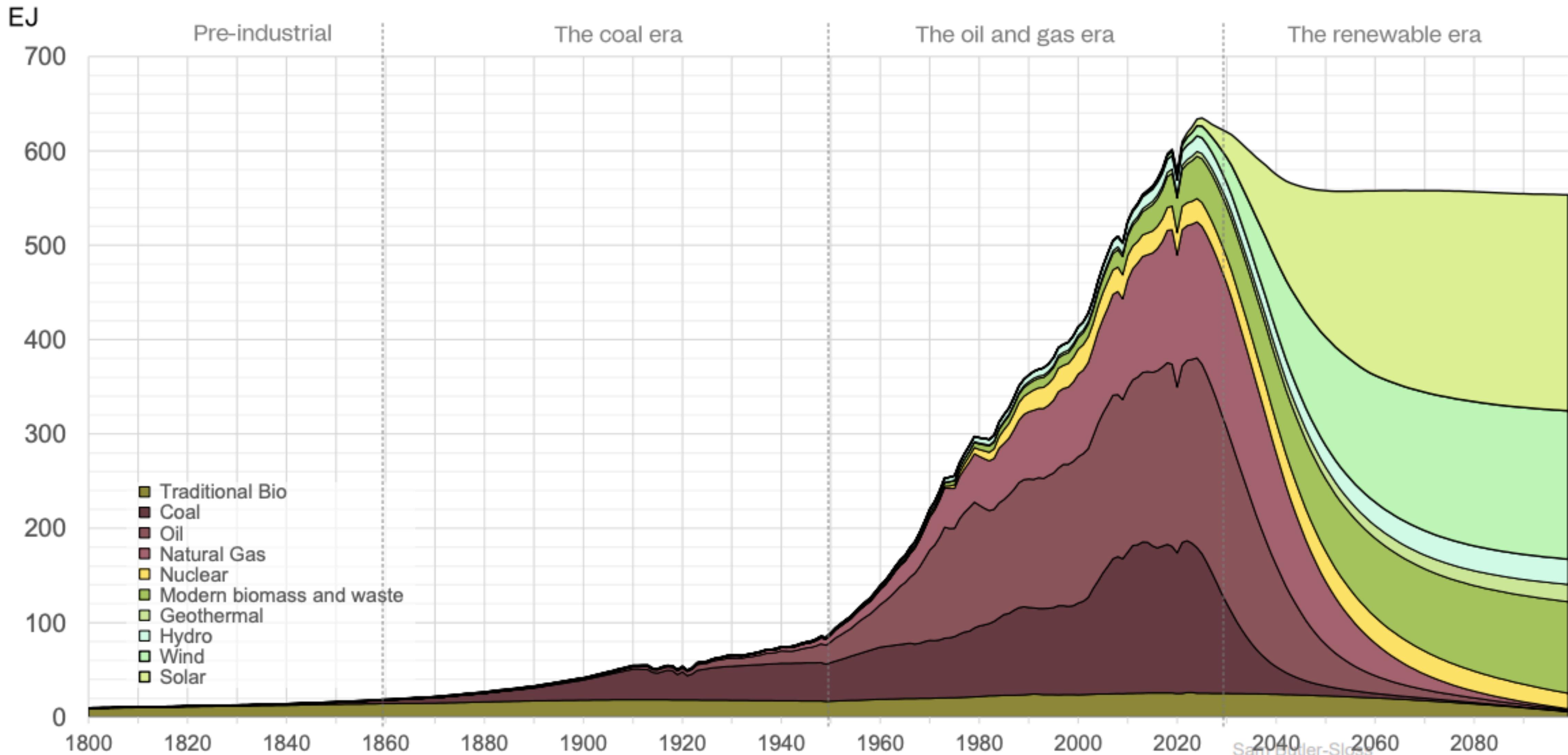


Phases of energy transitions and energy technologies

Aim for today

- Understand the phases of energy transitions and technological development
- Understand how mechanisms of transitions shape technological development over the phases of transition
- Be able to critically examine a transition and identify the key mechanisms and the phase of deployment

The global energy transition



Phases of to net-zero energy transitions

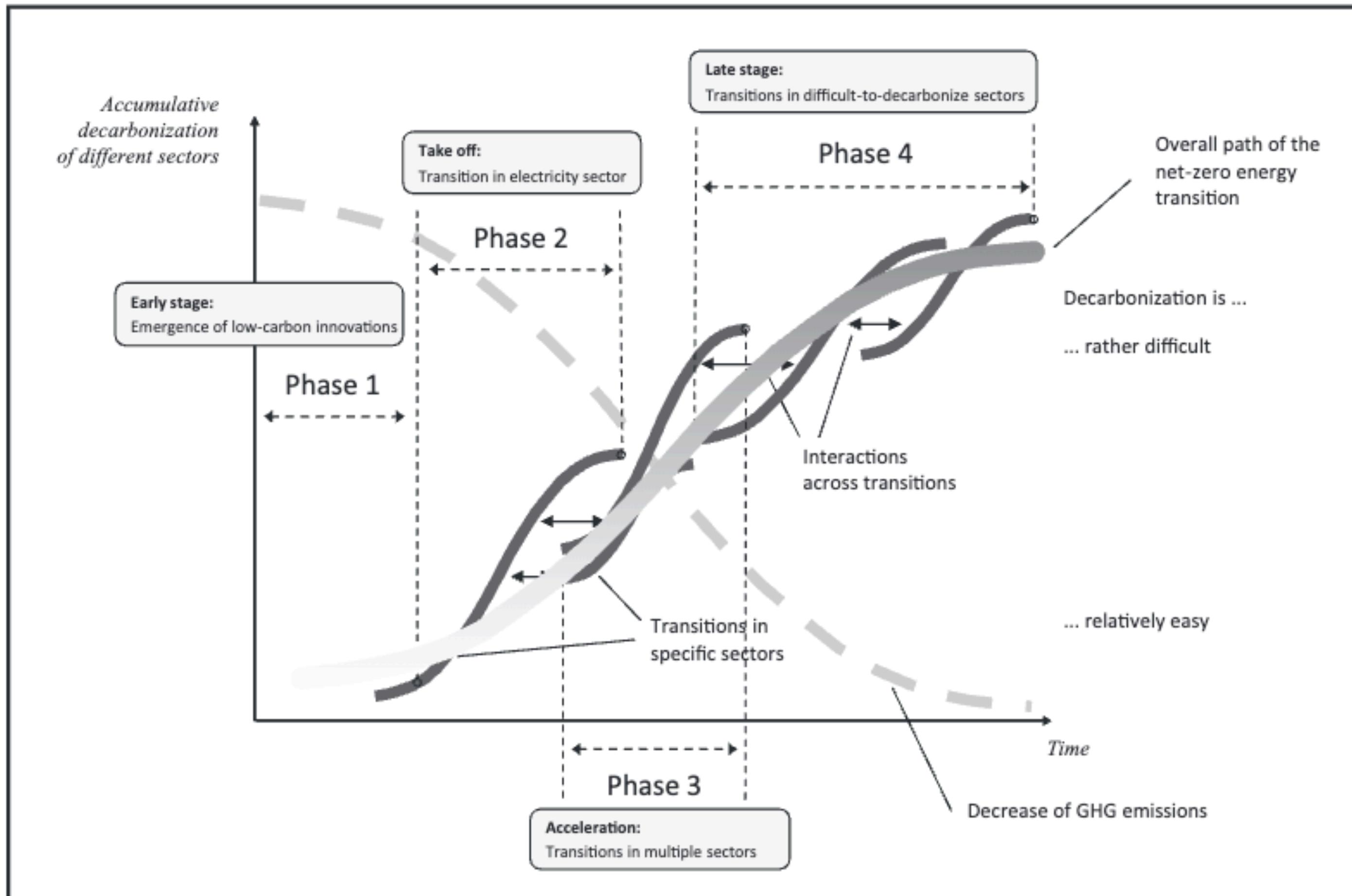


Figure 7.4 Low-carbon innovations and individual transitions build toward net-zero: schematic model of interdependent innovation dynamics and sectoral transition. Dynamics of decline have been omitted for the sake of simplicity.

Phases to net-zero transitions

	Phase 1: Emergence of low-carbon innovations	Phase 2: Transition in electricity sector	Phase 3: Transition in multiple sectors	Phase 4: Transitions in difficult to decarbonize sectors
Estimated time	1980-2010	Since 2010	Since 2015	Since 2020
Sectoral scope	-	Focus on electricity	Multiple sectors	All sectors
Decarbonisation strategy	-	Low-carbon electrification	“Electrify everything”	Strategies to reach difficult-to-abate sectors

Phases of to net-zero transitions

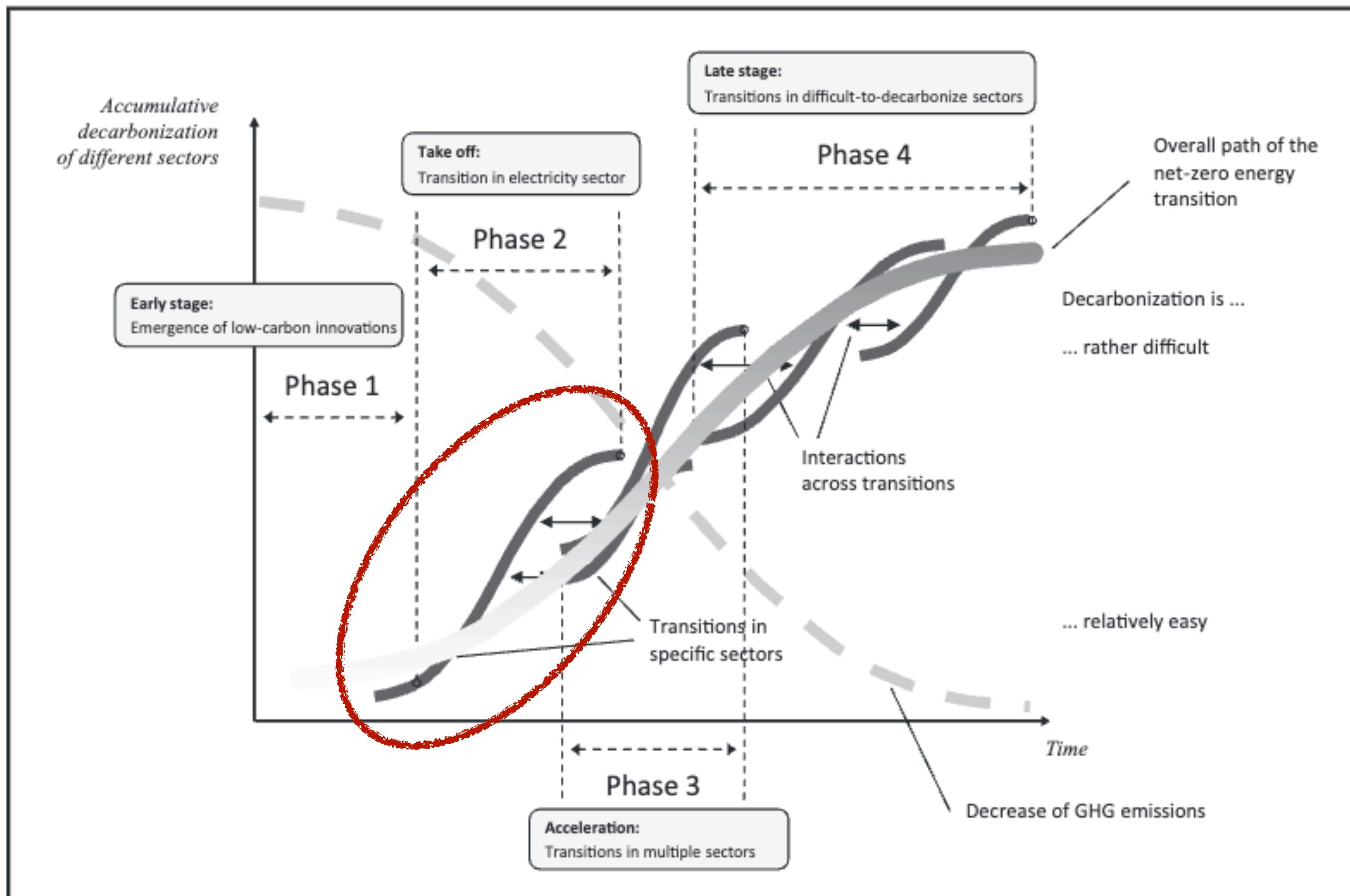


Figure 7.4 Low-carbon innovations and individual transitions build toward net-zero: schematic model of interdependent innovation dynamics and sectoral transition. Dynamics of decline have been omitted for the sake of simplicity.

But how can we say something about feasibility? And give good policy advice?

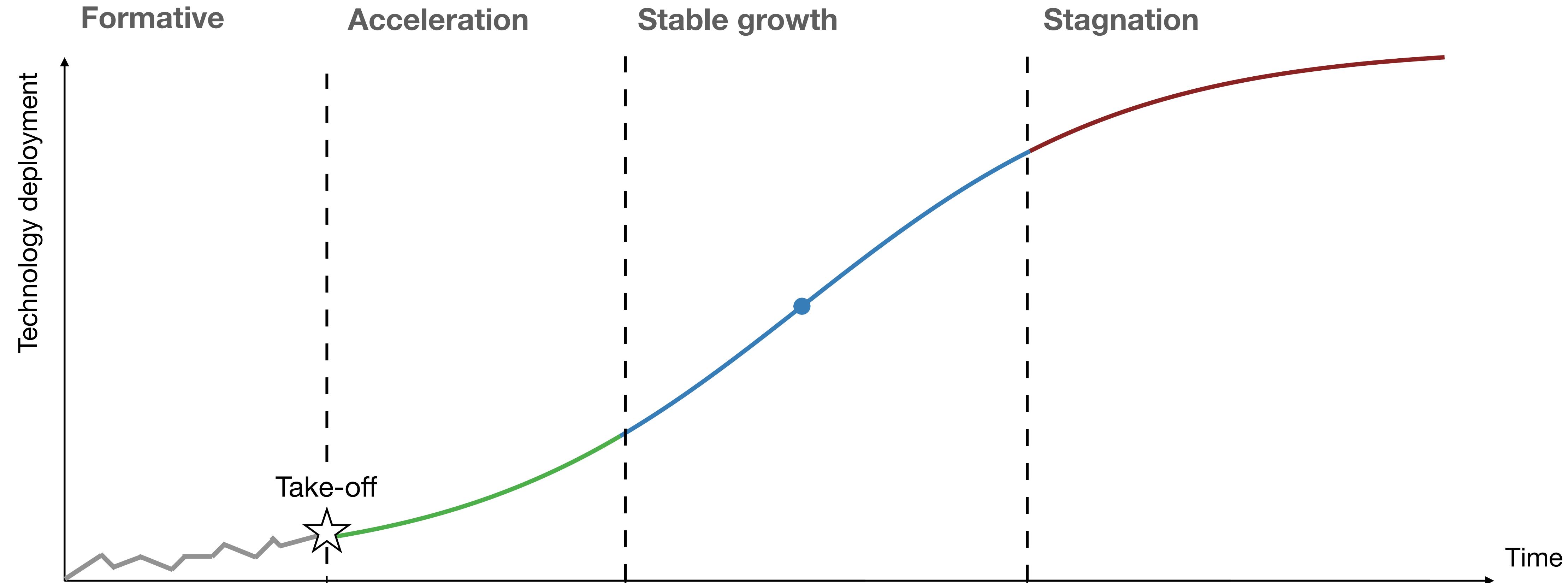
KÄRNKRAFTENS FRAMTID

Pourmokhtari: Sverige behöver tio
nya kärnreaktorer

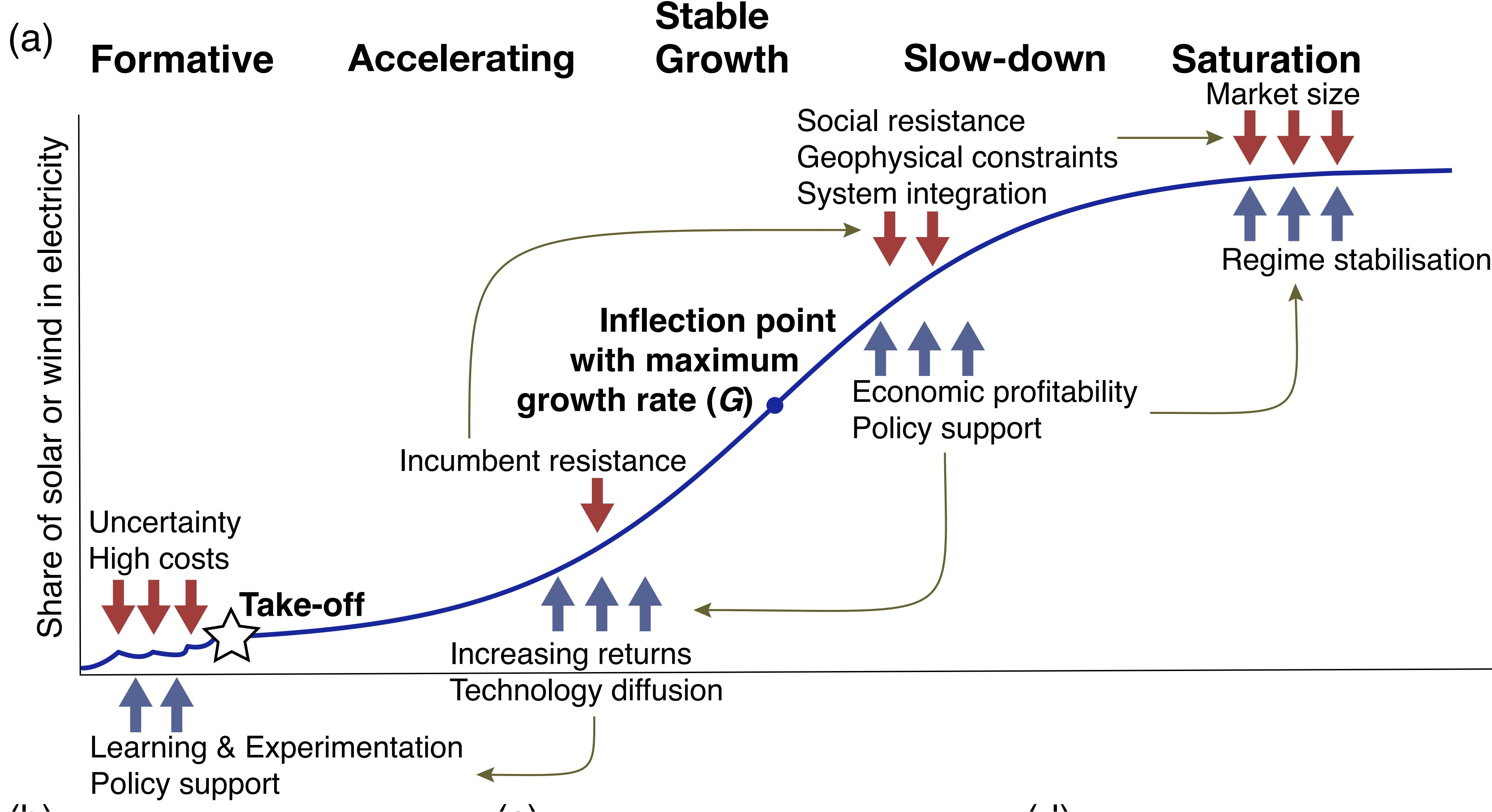


Klimat- och miljöminister Romina Pourmokhtari har pressträff med Strålsäkerhetsmyndighetens vikarierande generaldirektör Michael Knochenhauer om framtida kärnkraft. Bild: Ali Lorestani/TT

Four phases of *technology growth*



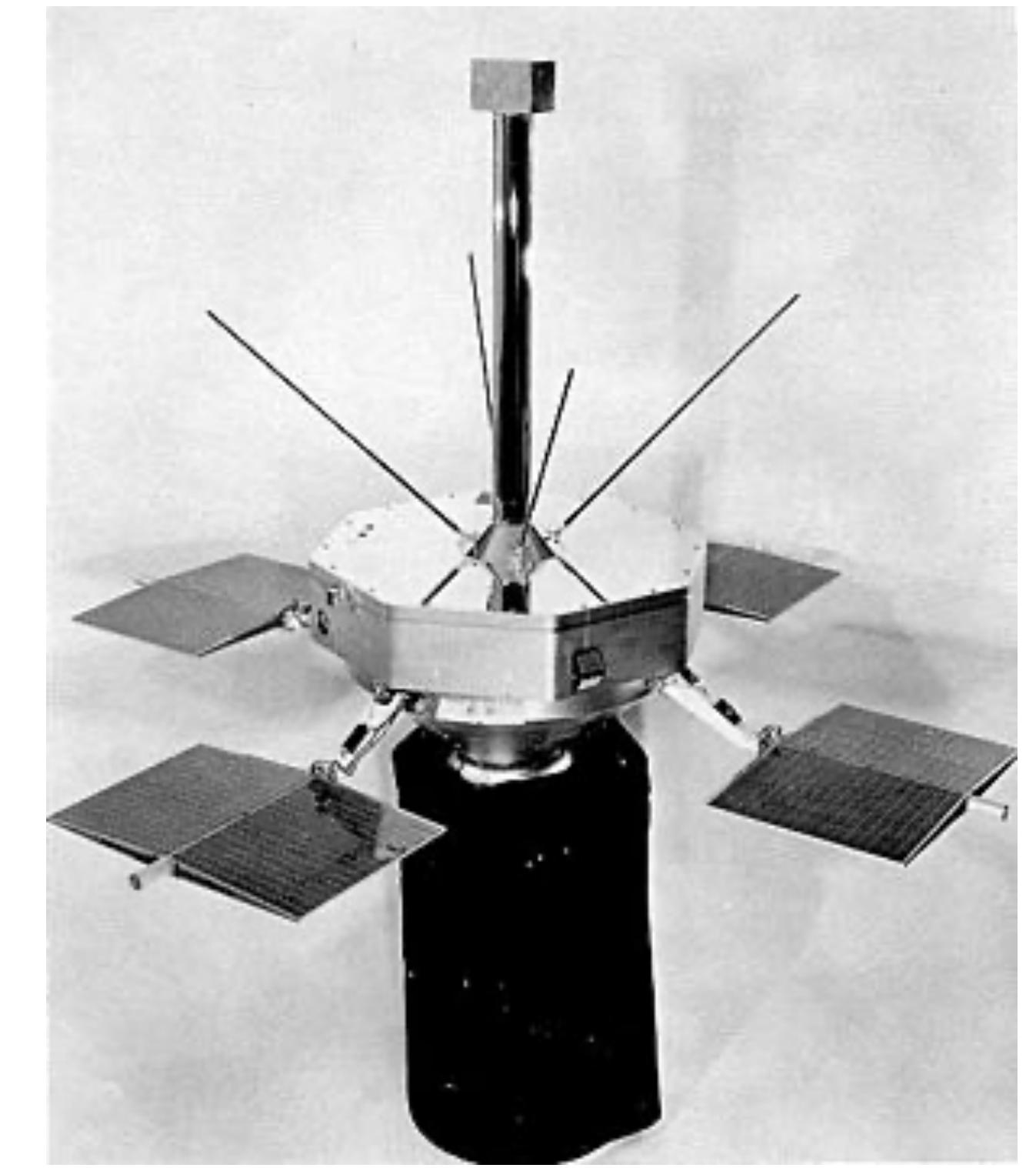
Mechanisms over the S-curve of technology adoption



Formative phase



Wind mill, 1930s

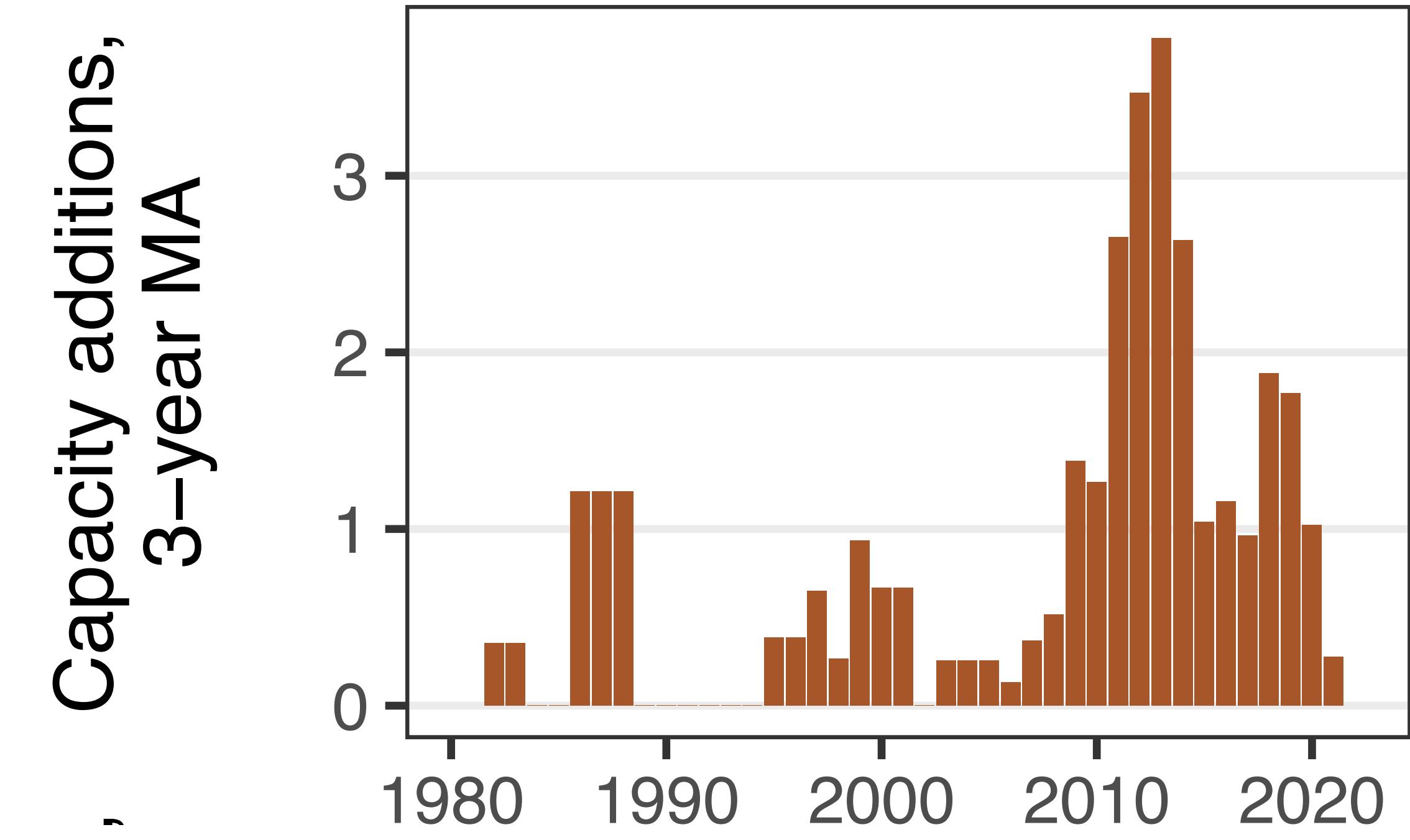
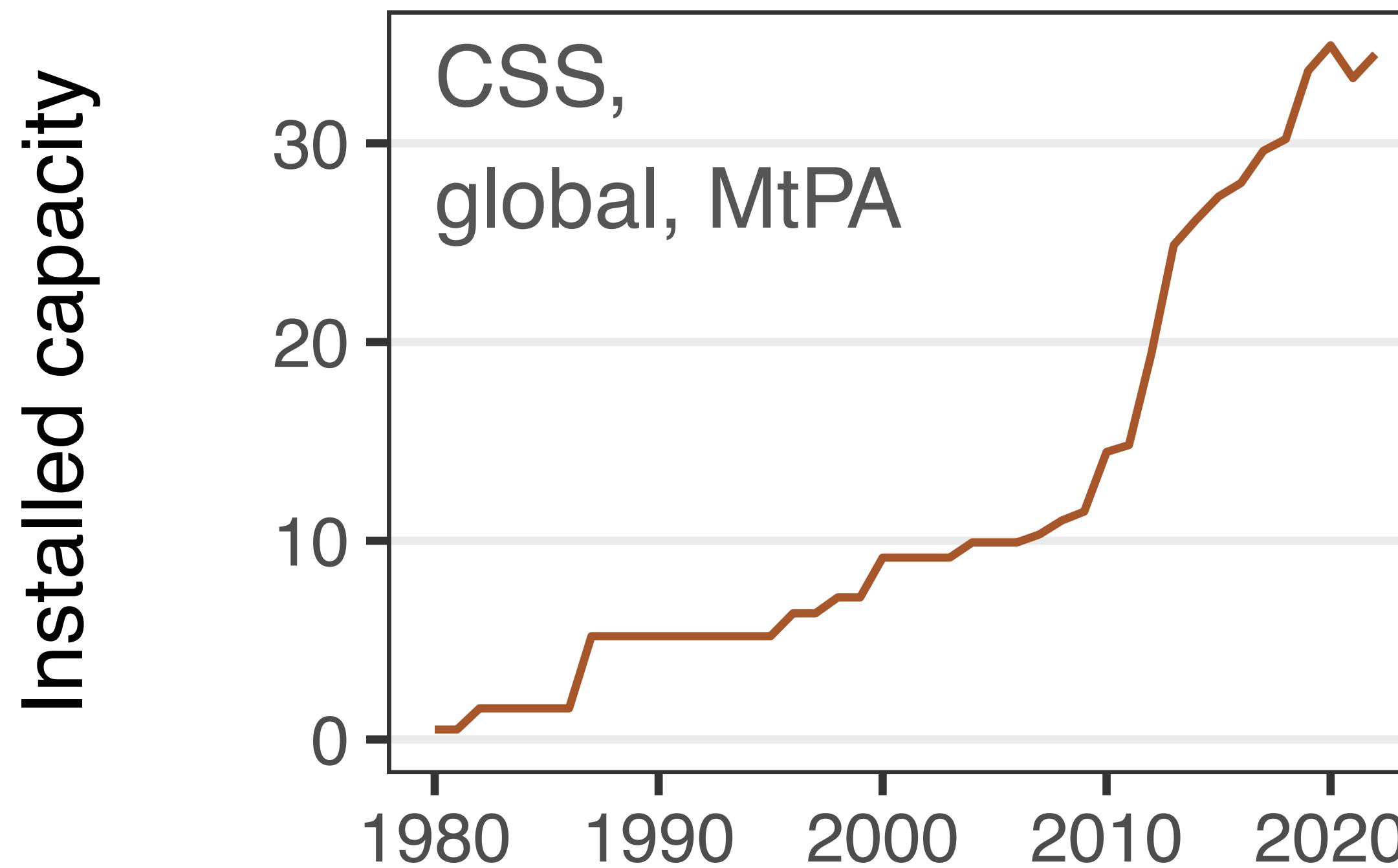


Solar-powered satellite, early 1960s

Mechanisms of the formative phase

- **Socio-technical** dominate
 - niche applications
 - experimentation
- **Political mechanisms**
 - low opposition – nothing to oppose
- **Techno-economic mechanisms**
 - high costs

Formative phase example – global CCS deployment and additions in MtPA



End of the formative phase

- Reduction of uncertainty
- Cost and performance become suitable for broader markets
- (Often) Converging on a “dominant design”
- Transition to a smoother, more regular growth
- Starting mechanisms of “increasing returns”



Takeoff!

Acceleration phase



... ENERGY, ENVIRONMENT & RESOURCES

The Promise of Solar Power

BY MATT WILLIAMS | 5 MIN READ



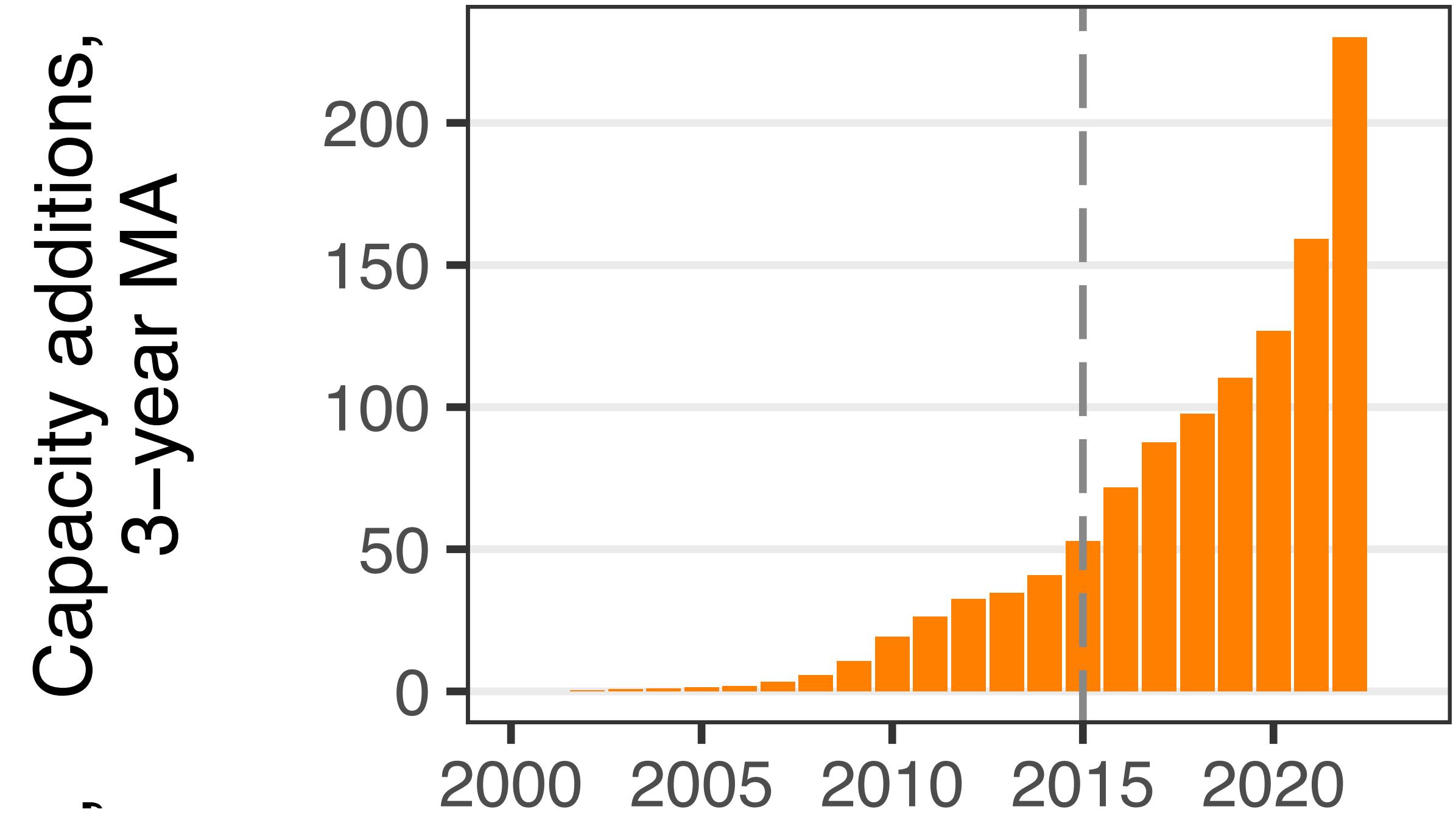
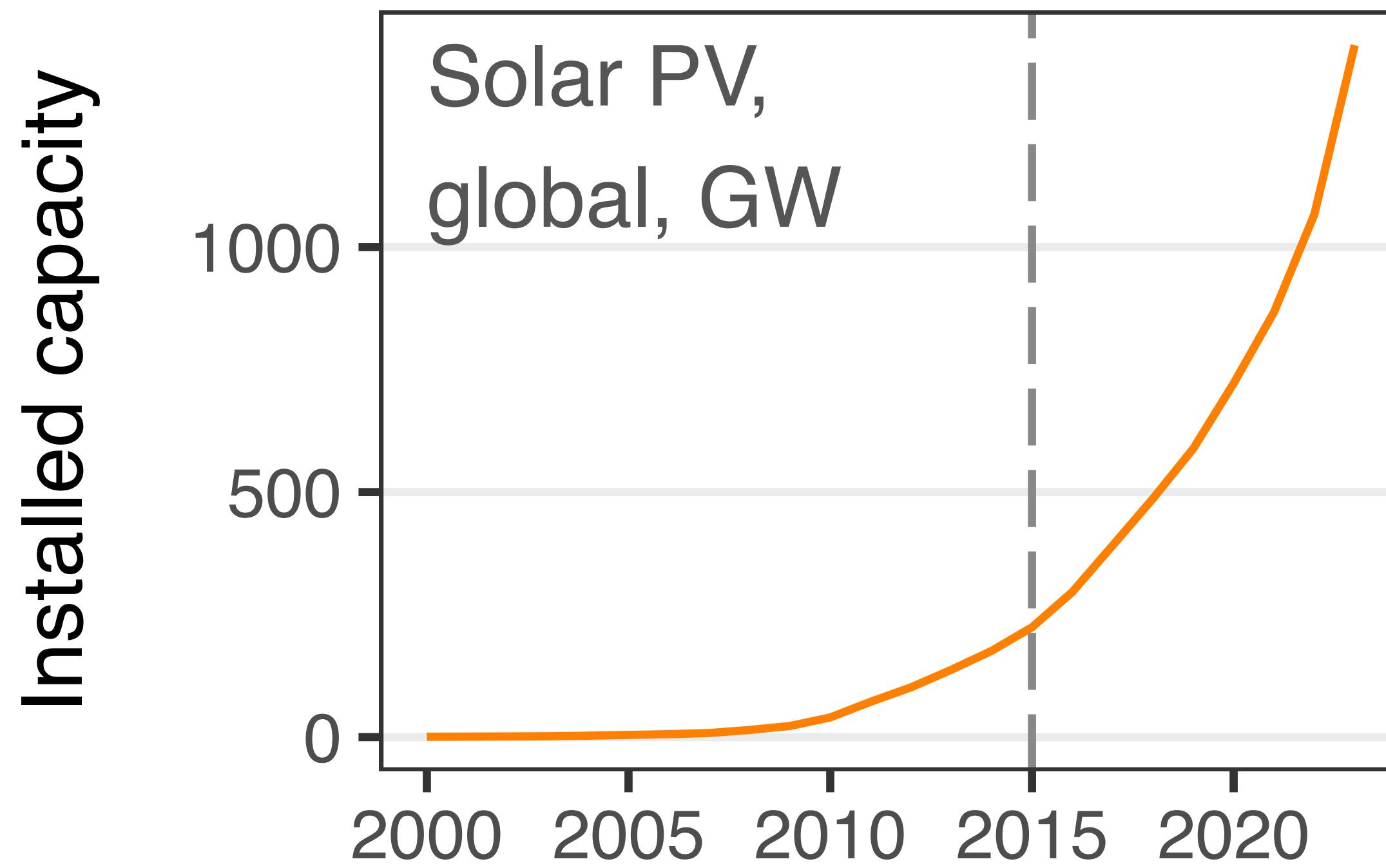
Solar Power has come a long way in recent years. Once considered to be the most promising amongst energy alternatives, it has now reached a point where it has become economically viable and even competitive. In fact, a recent report from the International Energy Agency states that photovoltaics and solar thermal systems could generate 27% percent of all electricity by 2050, which would make solar energy the single largest source of power by mid-century.



Mechanisms of the acceleration phase

- **Socio-technical** dominate
 - technological learning
- **Political mechanisms**
 - emerging beneficiaries
- **Techno-economic** mechanisms
 - falling costs

Acceleration phase example – global solar PV deployment and additions in GW



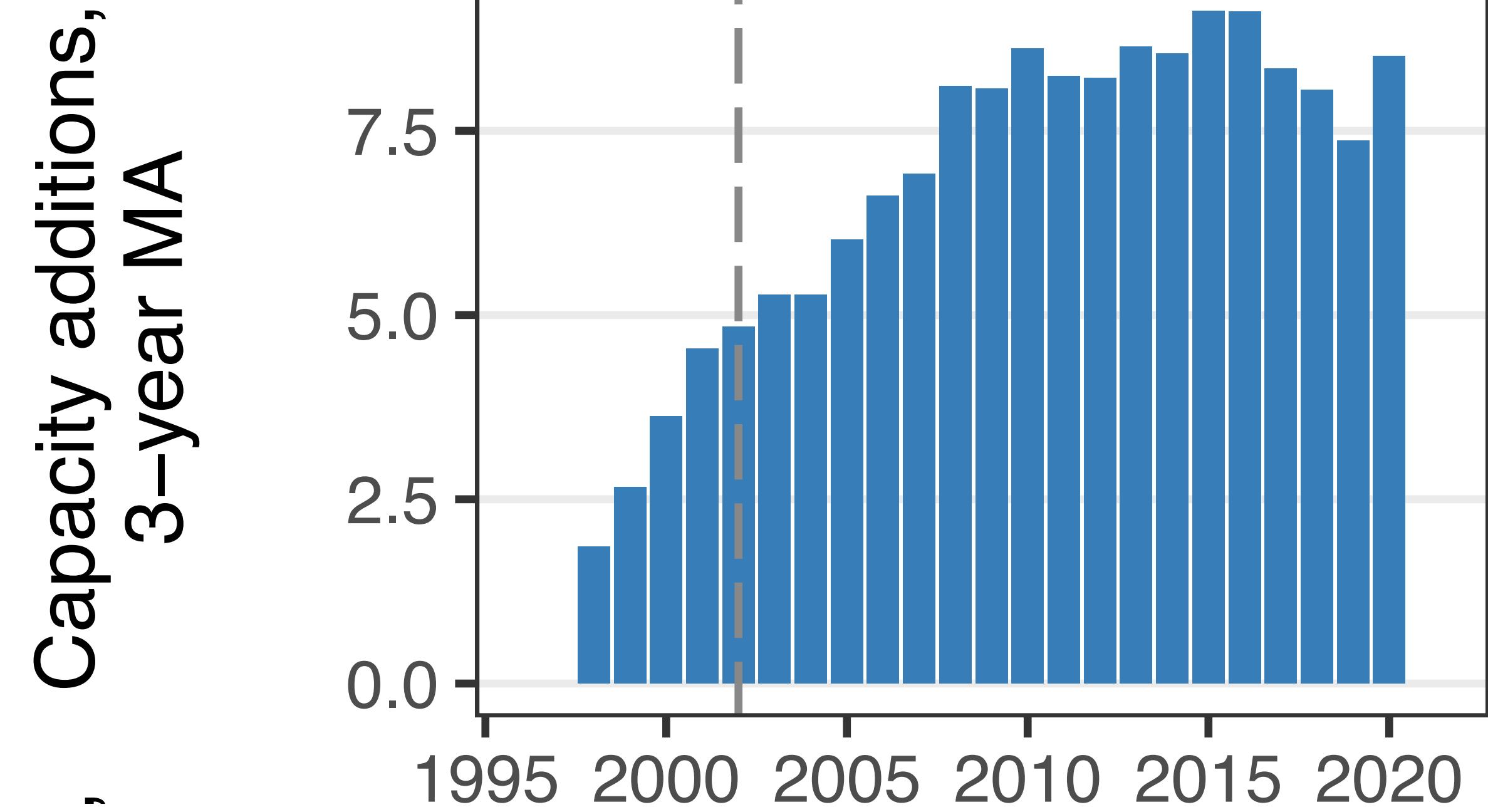
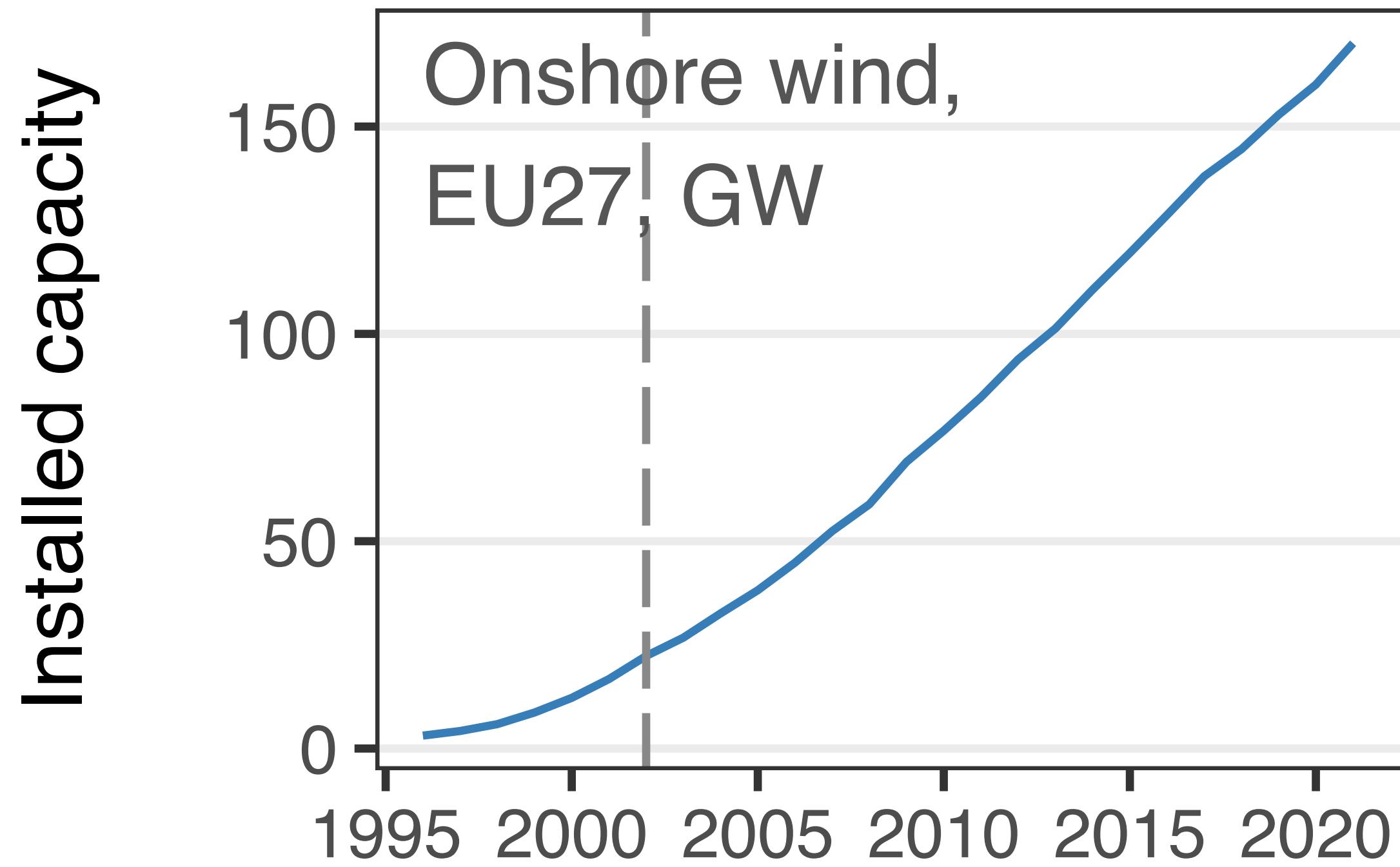
Stable growth phase



Stable growth mechanisms

- **Socio-technical**
 - increasing socio-technical complexity & innovation
- **Political mechanisms**
 - stronger interests and stronger opposition
- **Techno-economic mechanisms**
 - economic profitability
 - slower cost decline

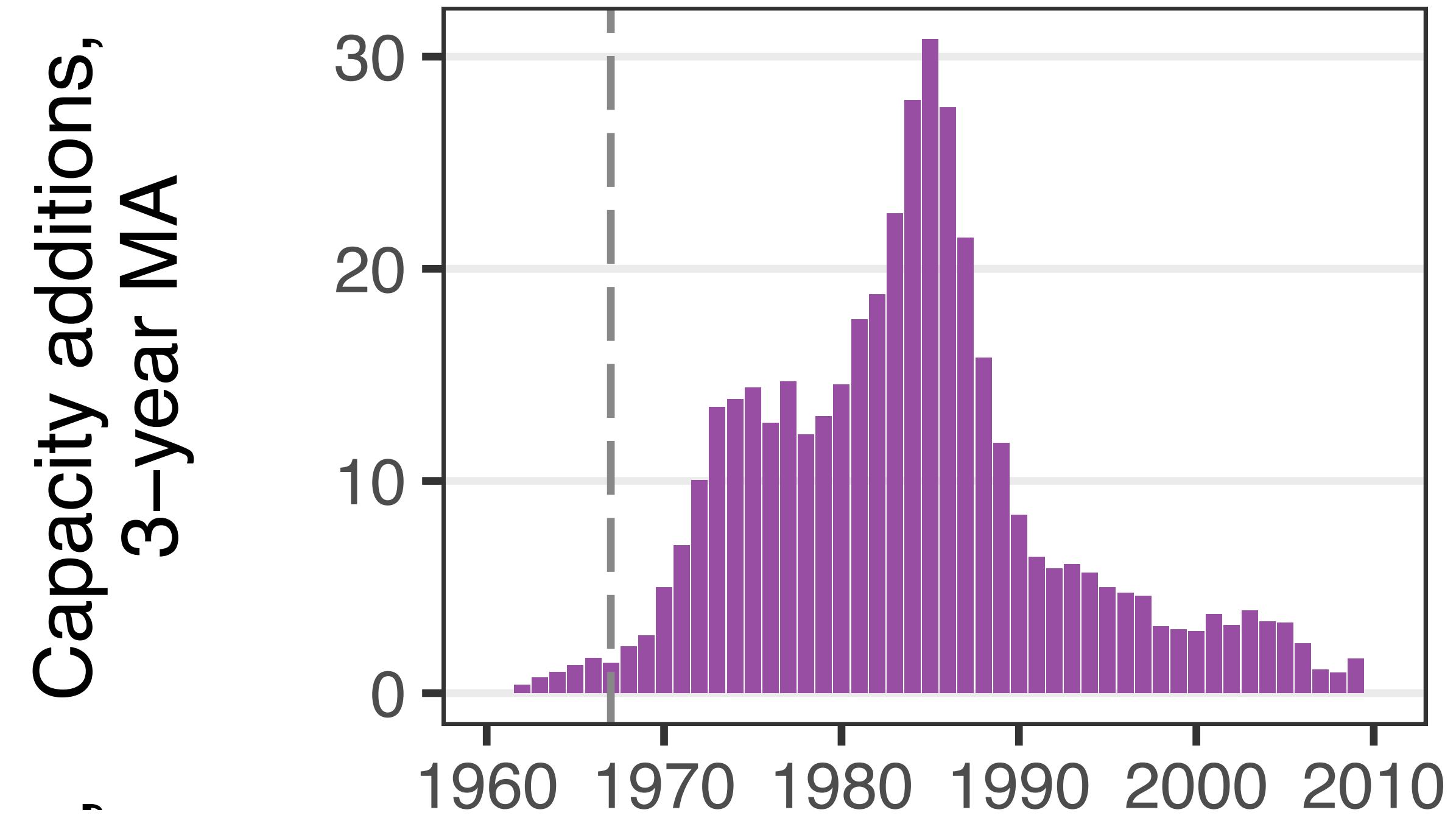
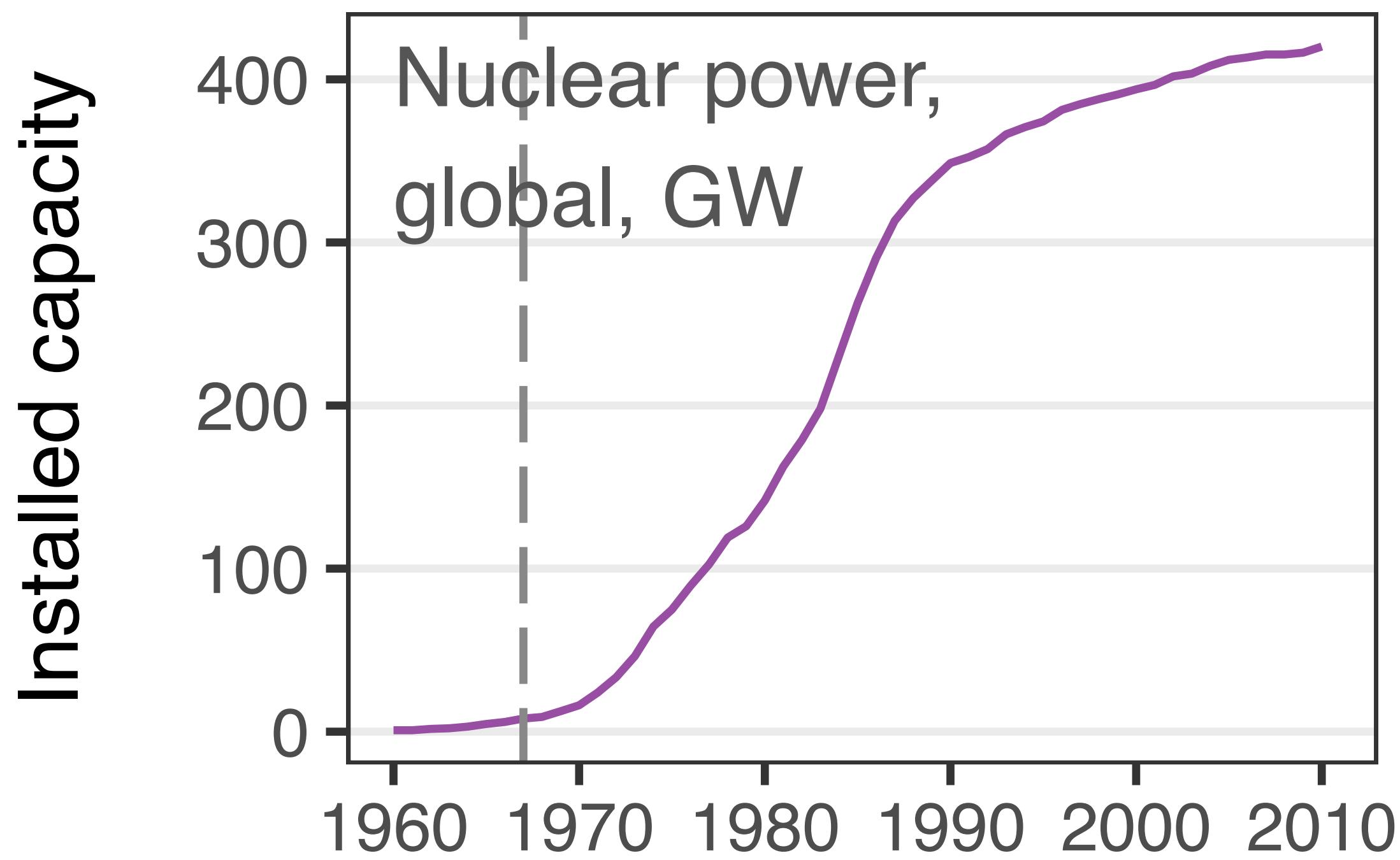
Stable growth phase example – onshore wind EU deployment and additions in GW



Slow-down and Saturation

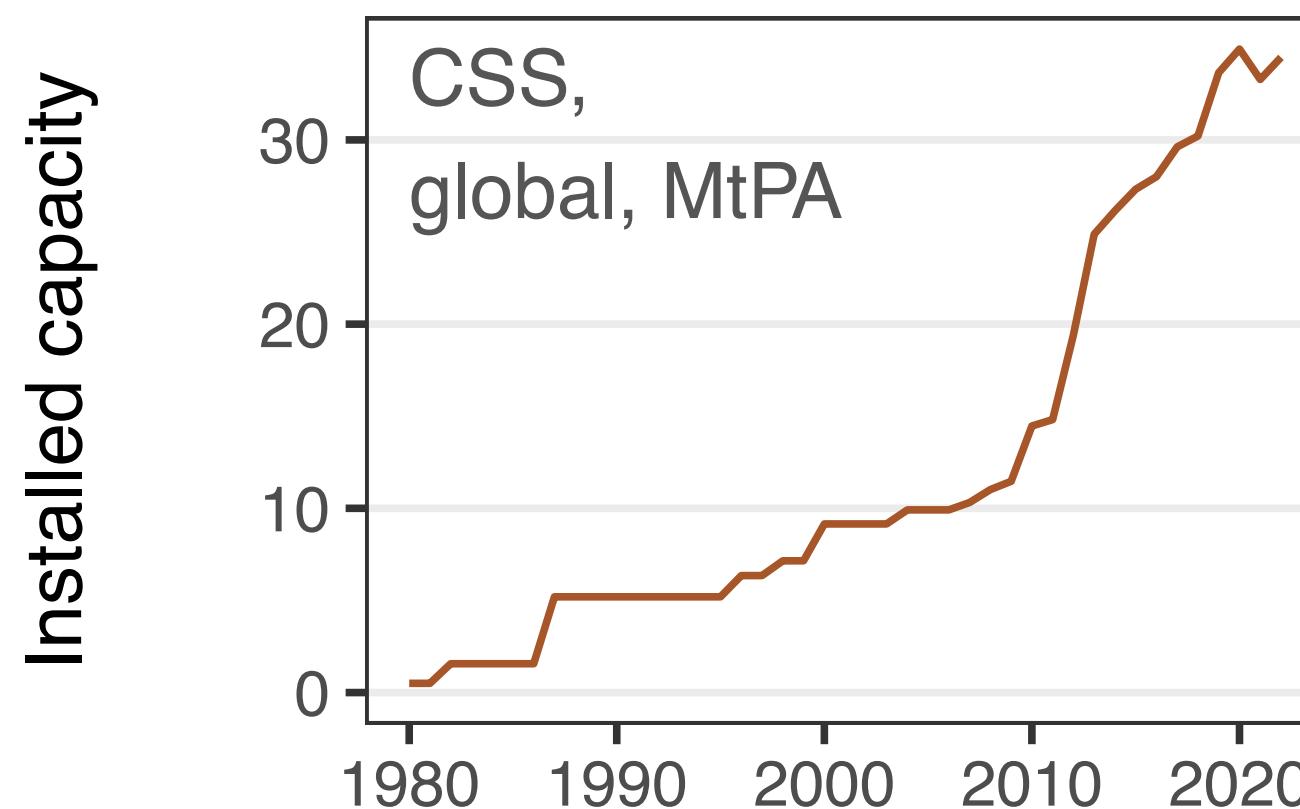
- **Socio-technical**
 - slower innovation and regime stabilisation
- **Political mechanisms**
 - policy normalisation
- **Techno-economic mechanisms**
 - geophysical and market limits

Stagnation phase example – global nuclear power deployment and additions in GW

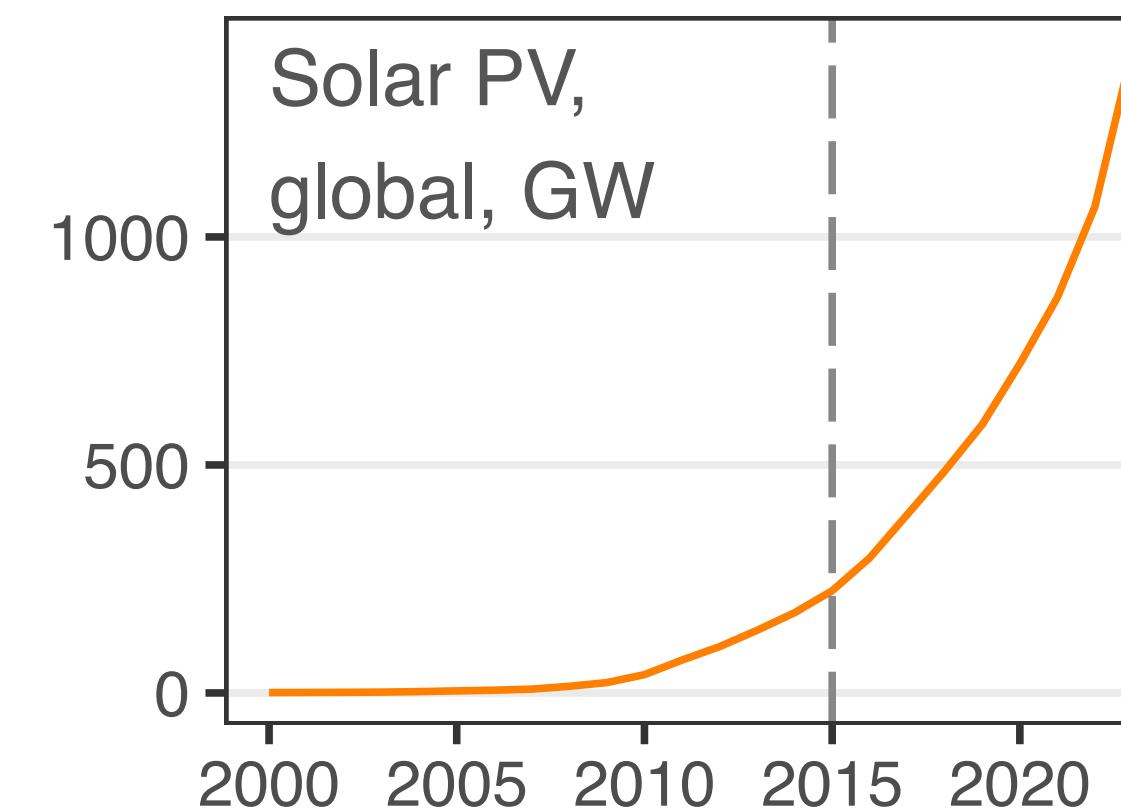


Four phases of technology growth deployment and additions

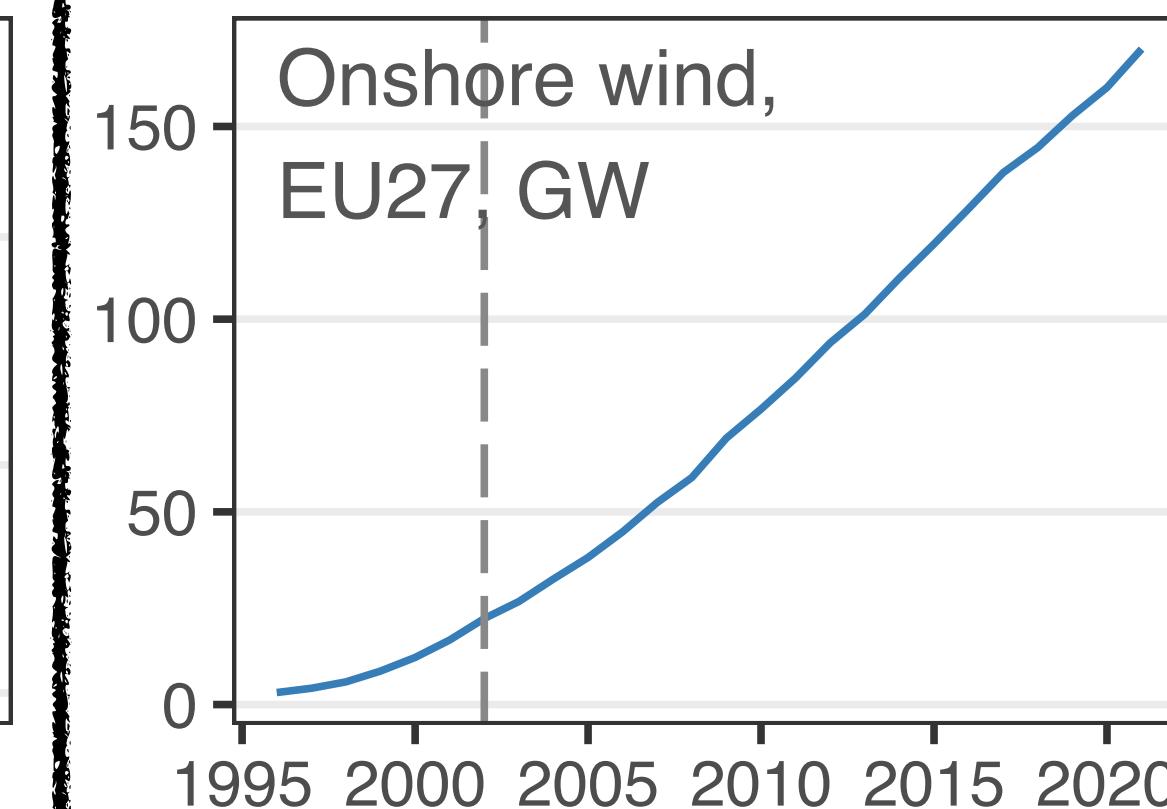
Formative



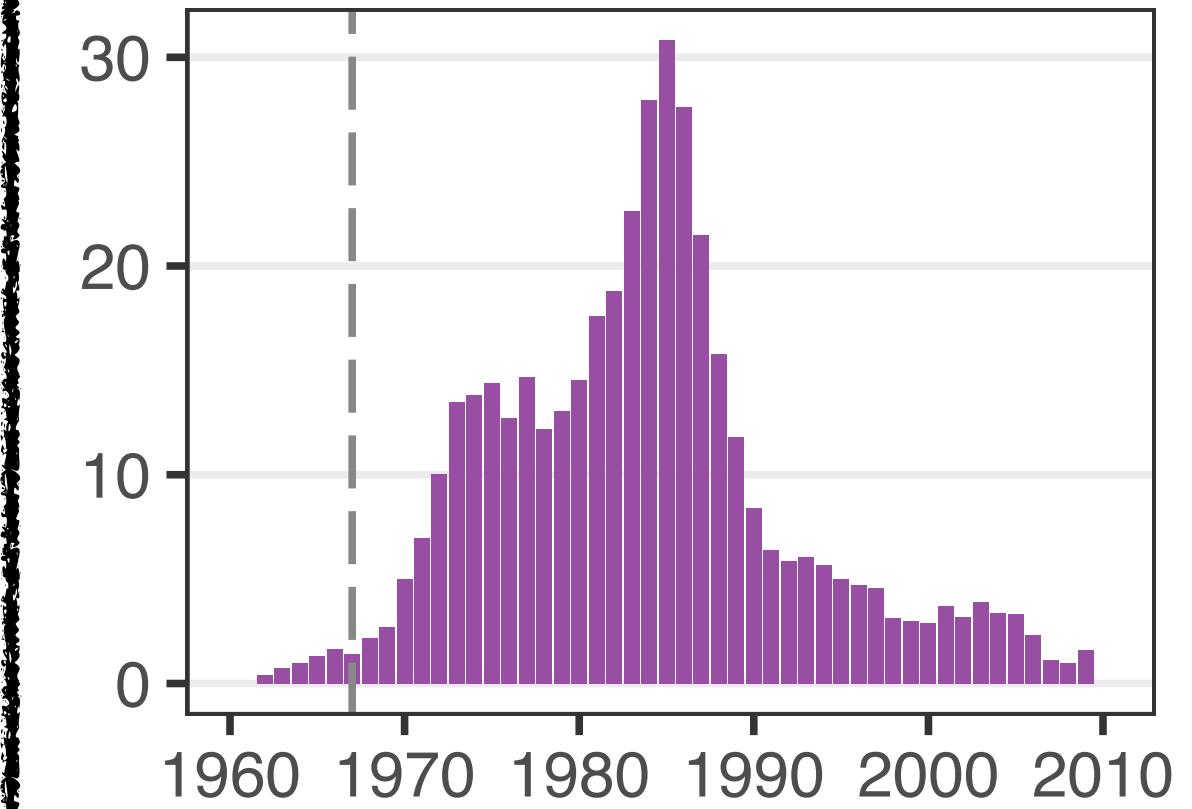
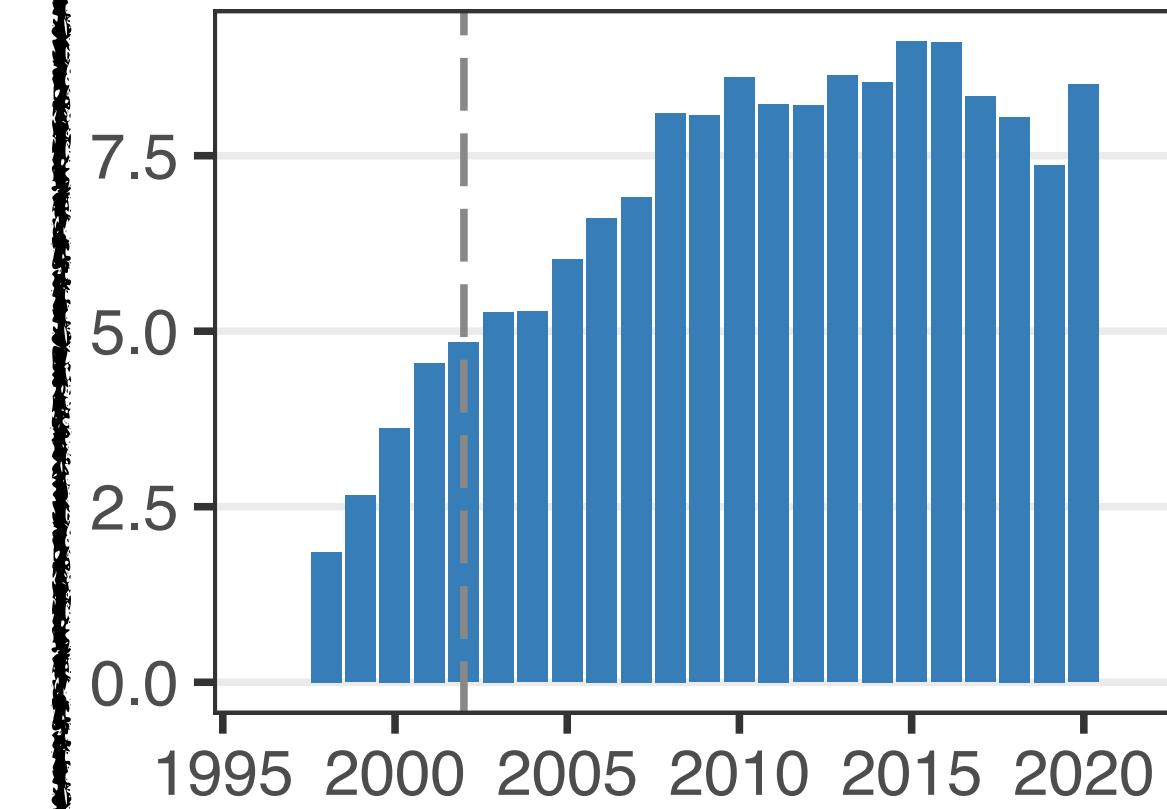
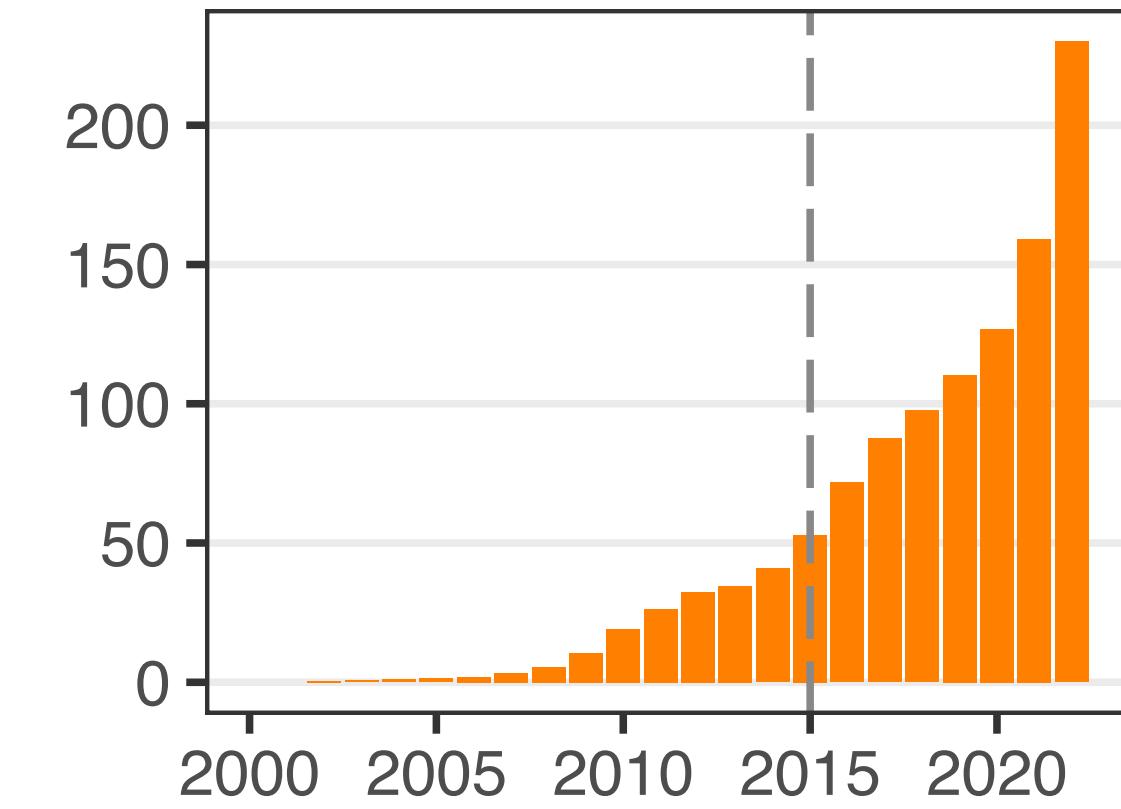
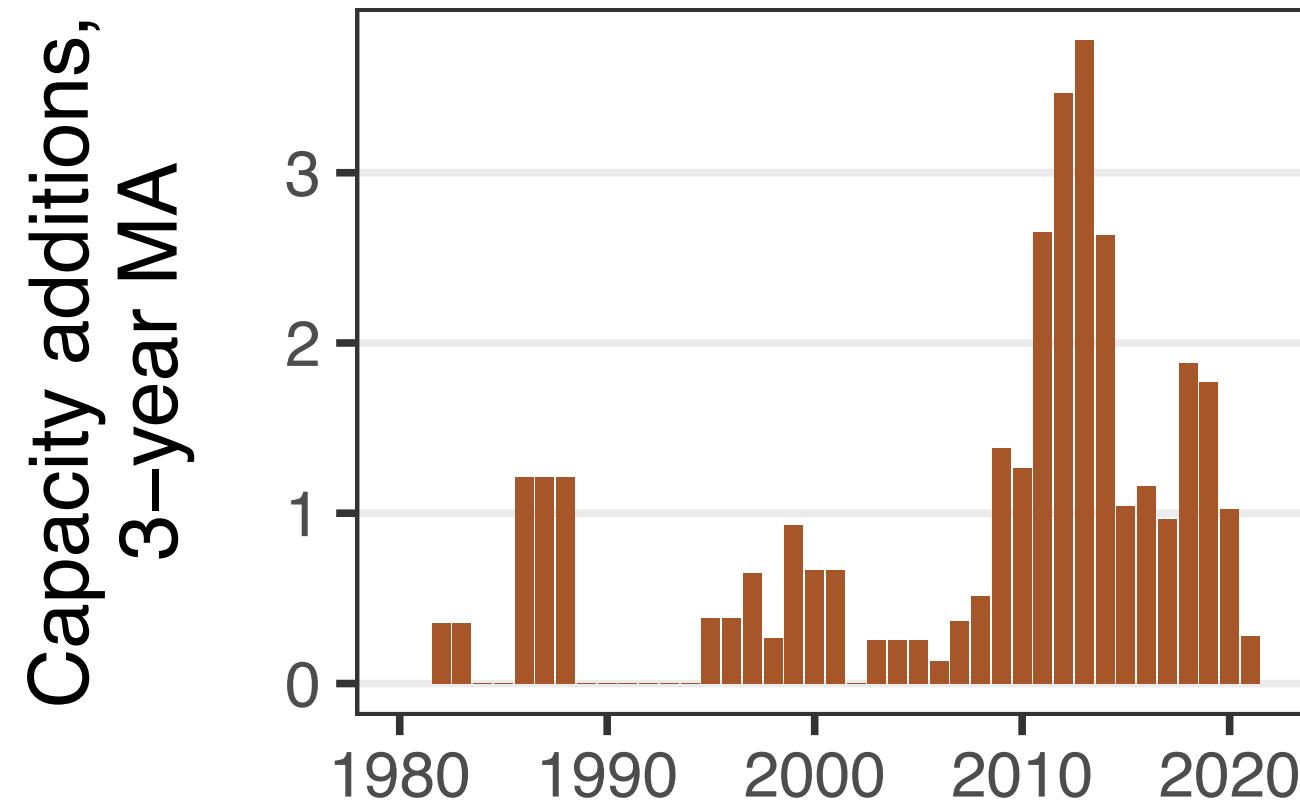
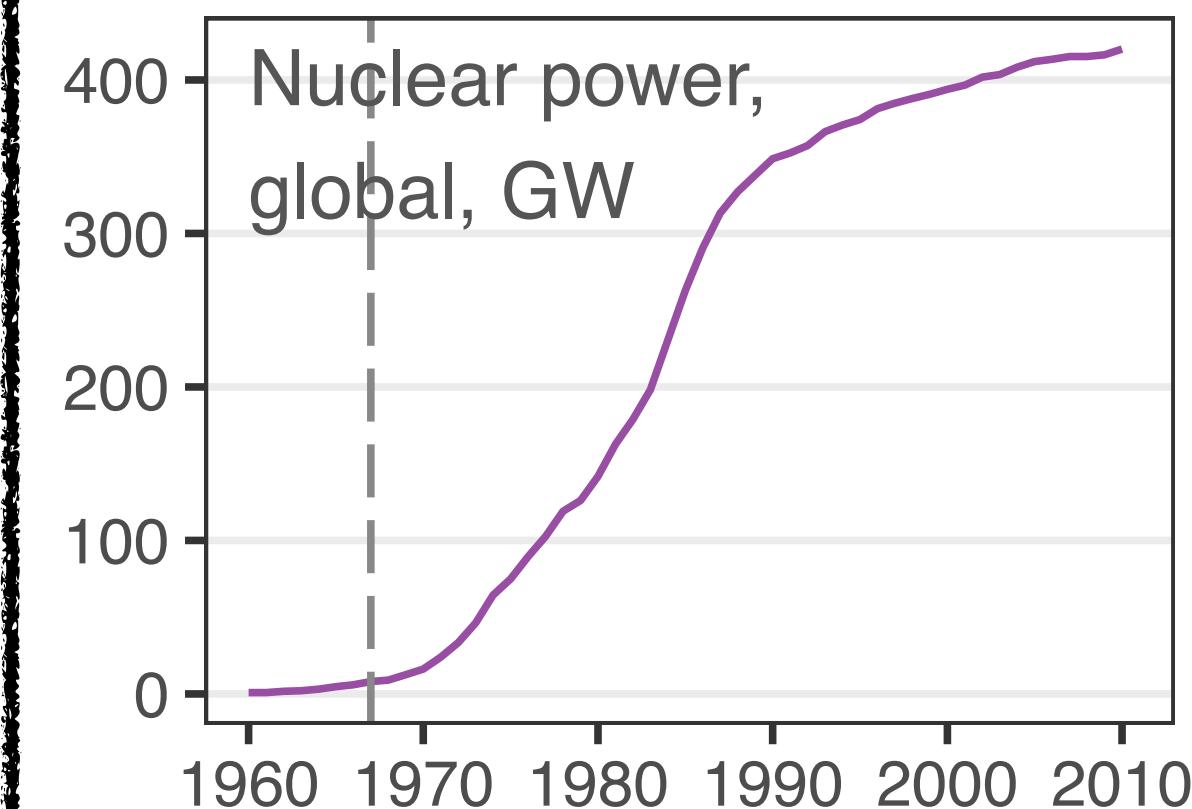
Acceleration



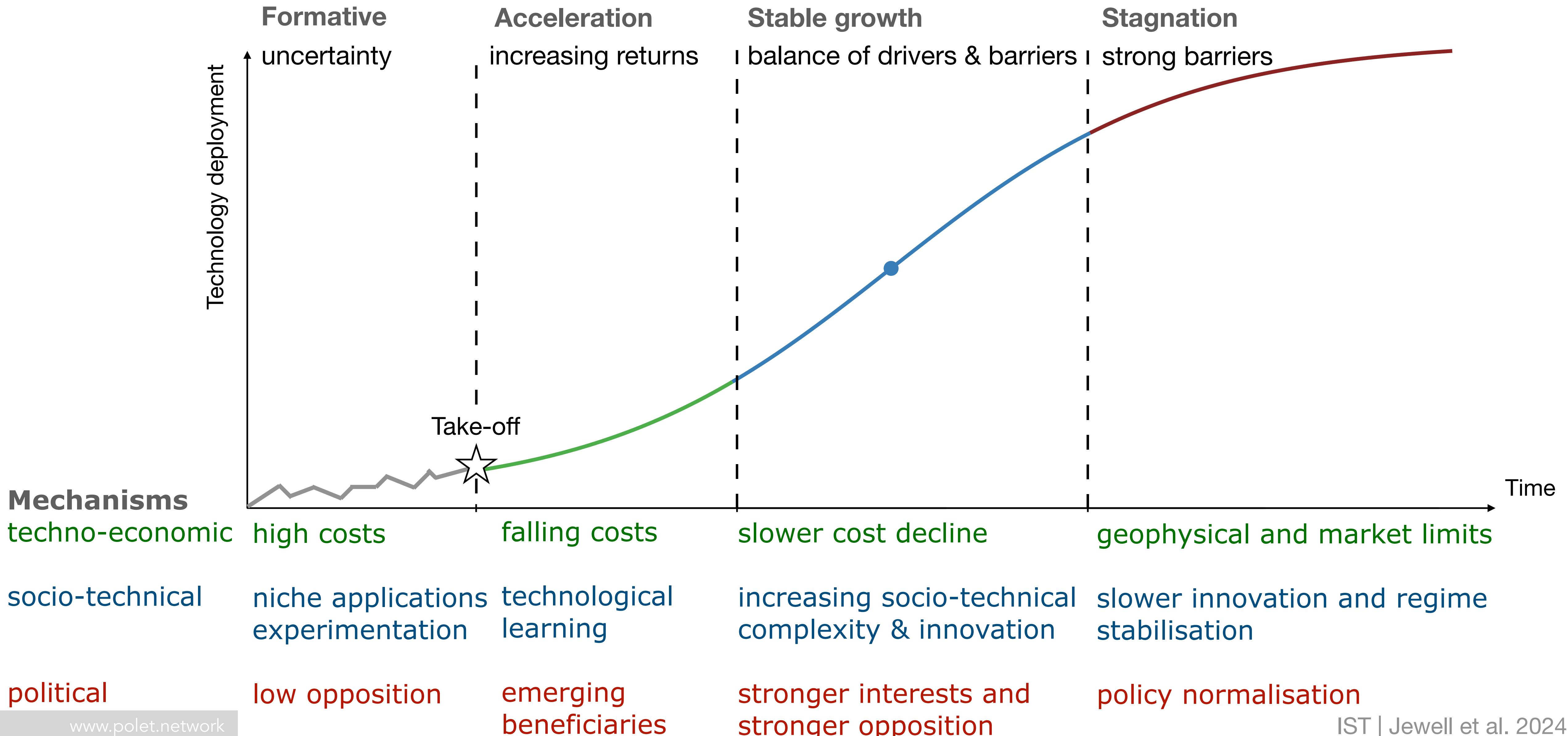
Stable growth



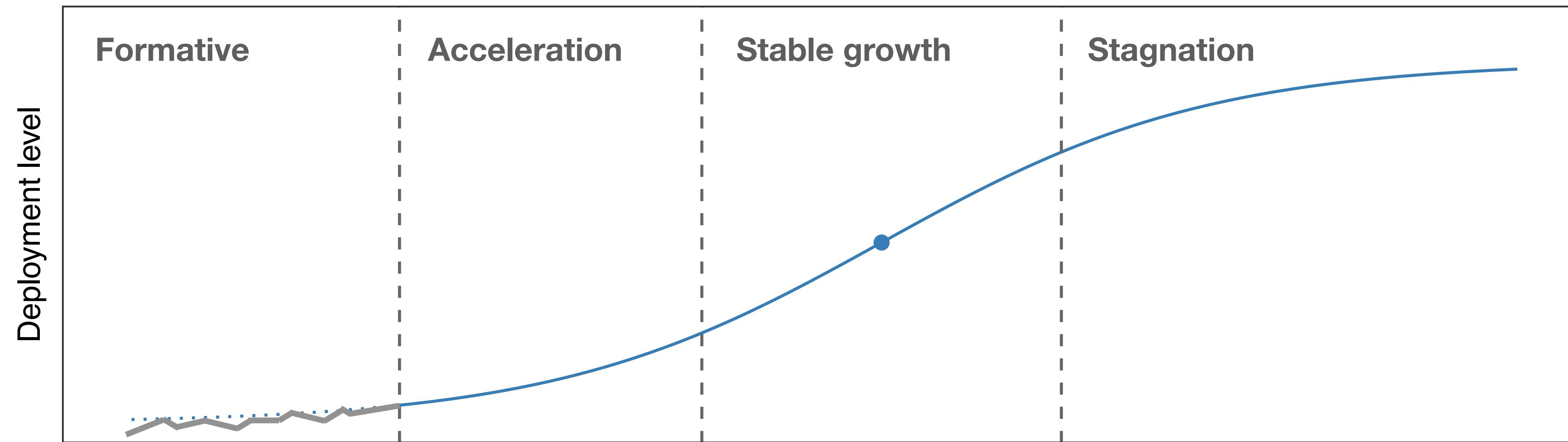
Stagnation



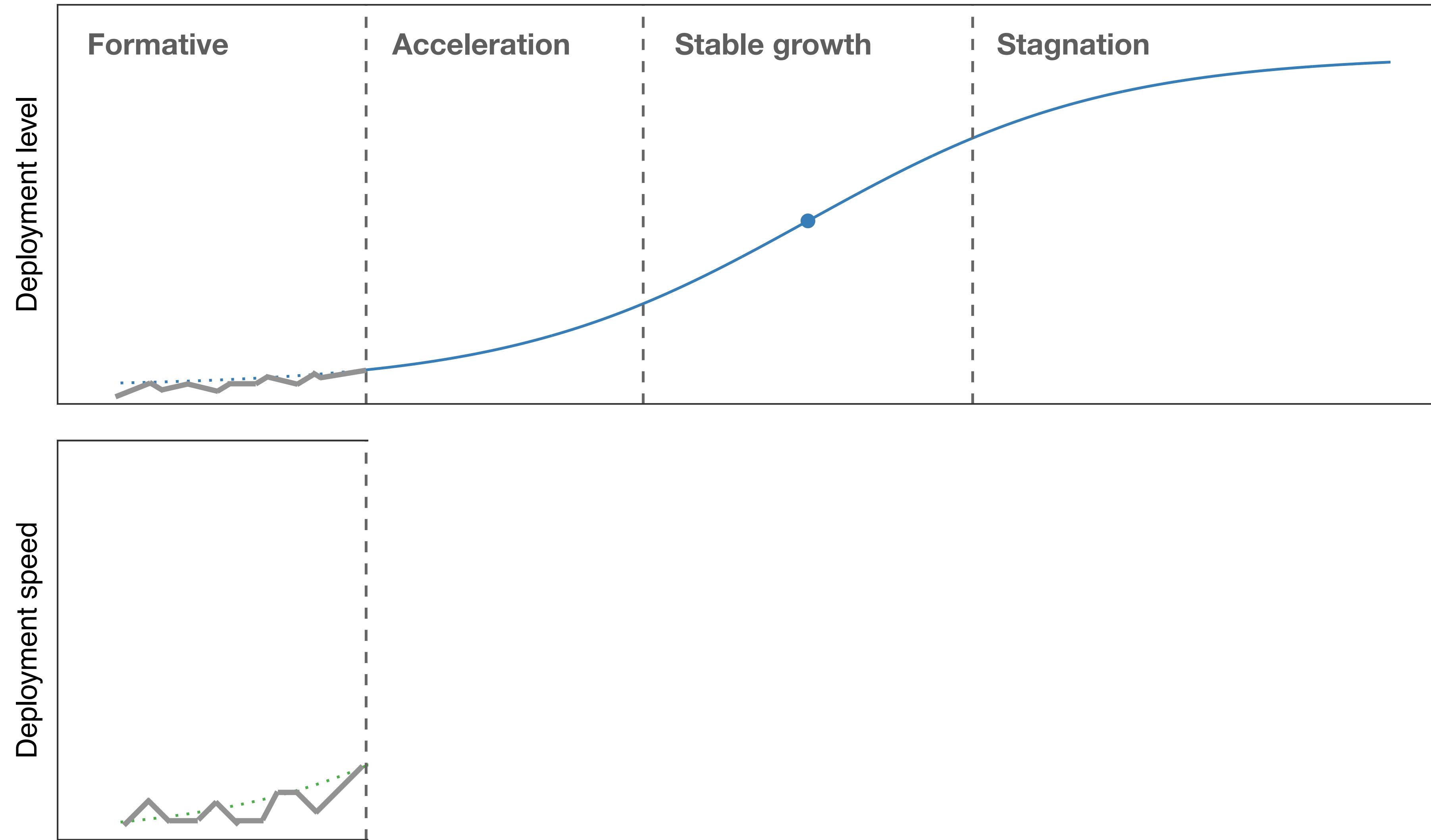
Four phases of technology growth



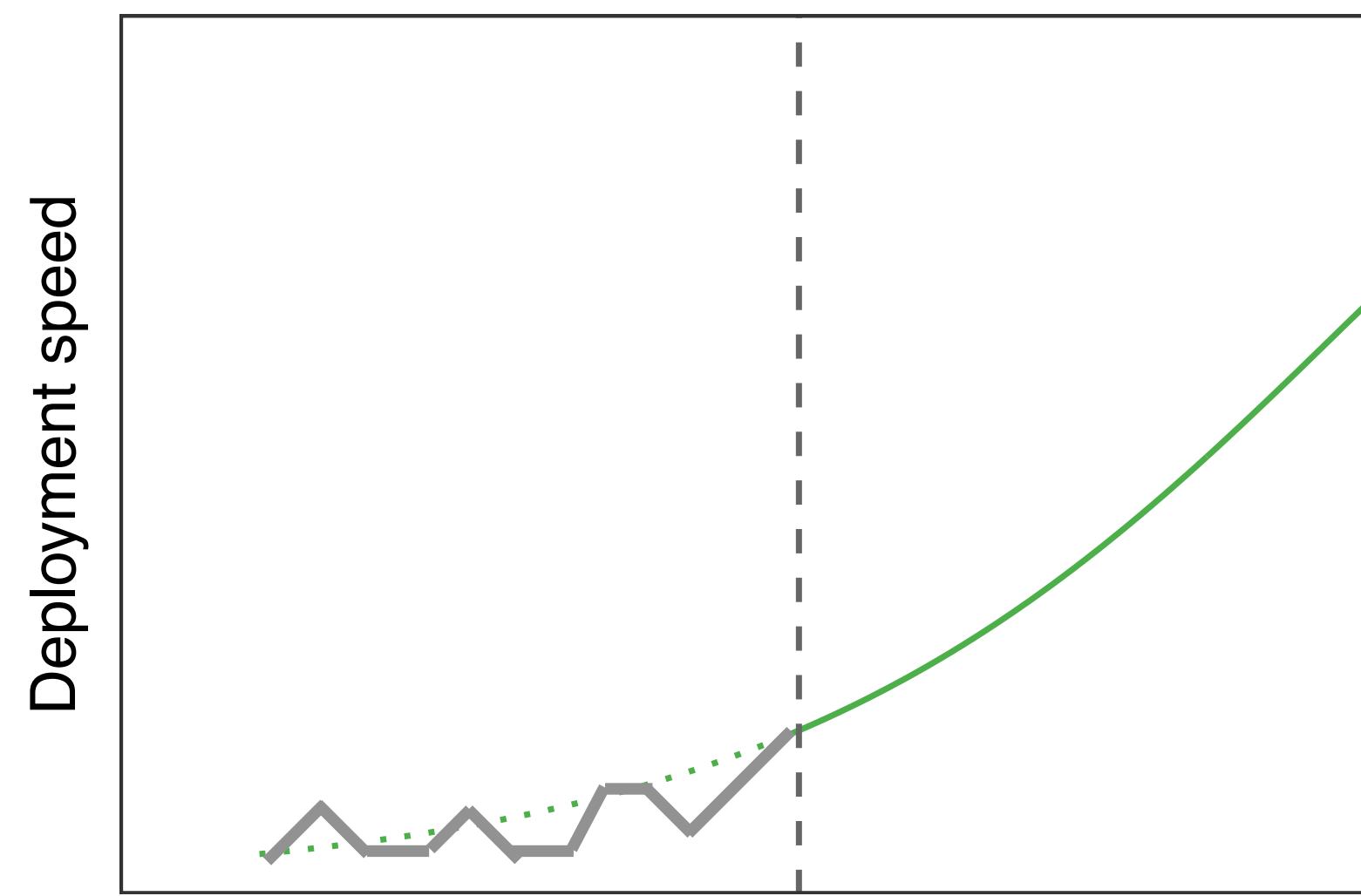
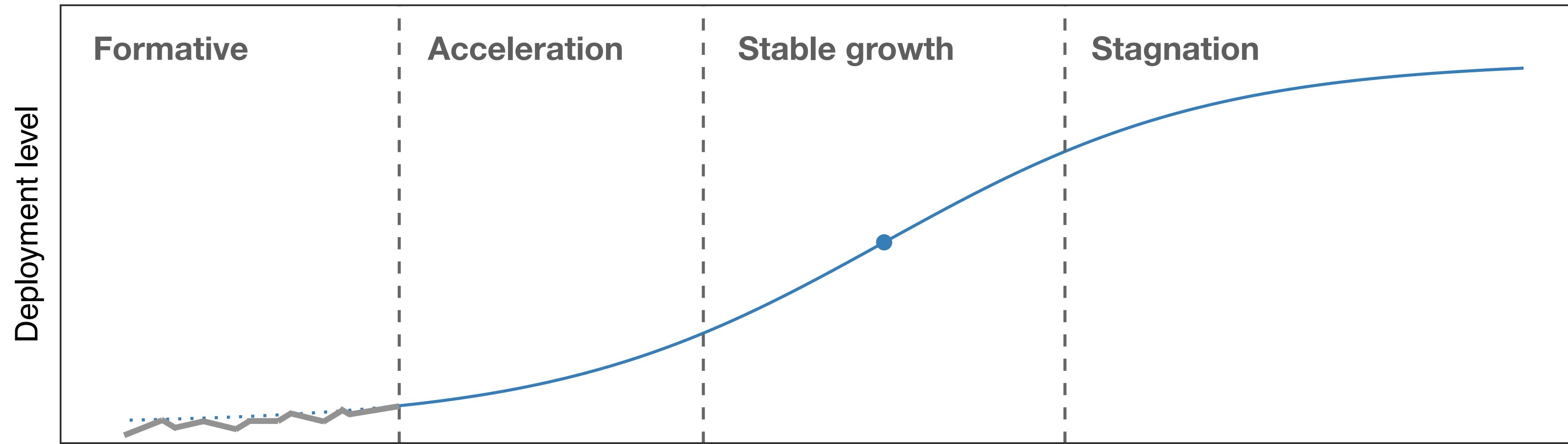
Mathematical expression of phases of growth



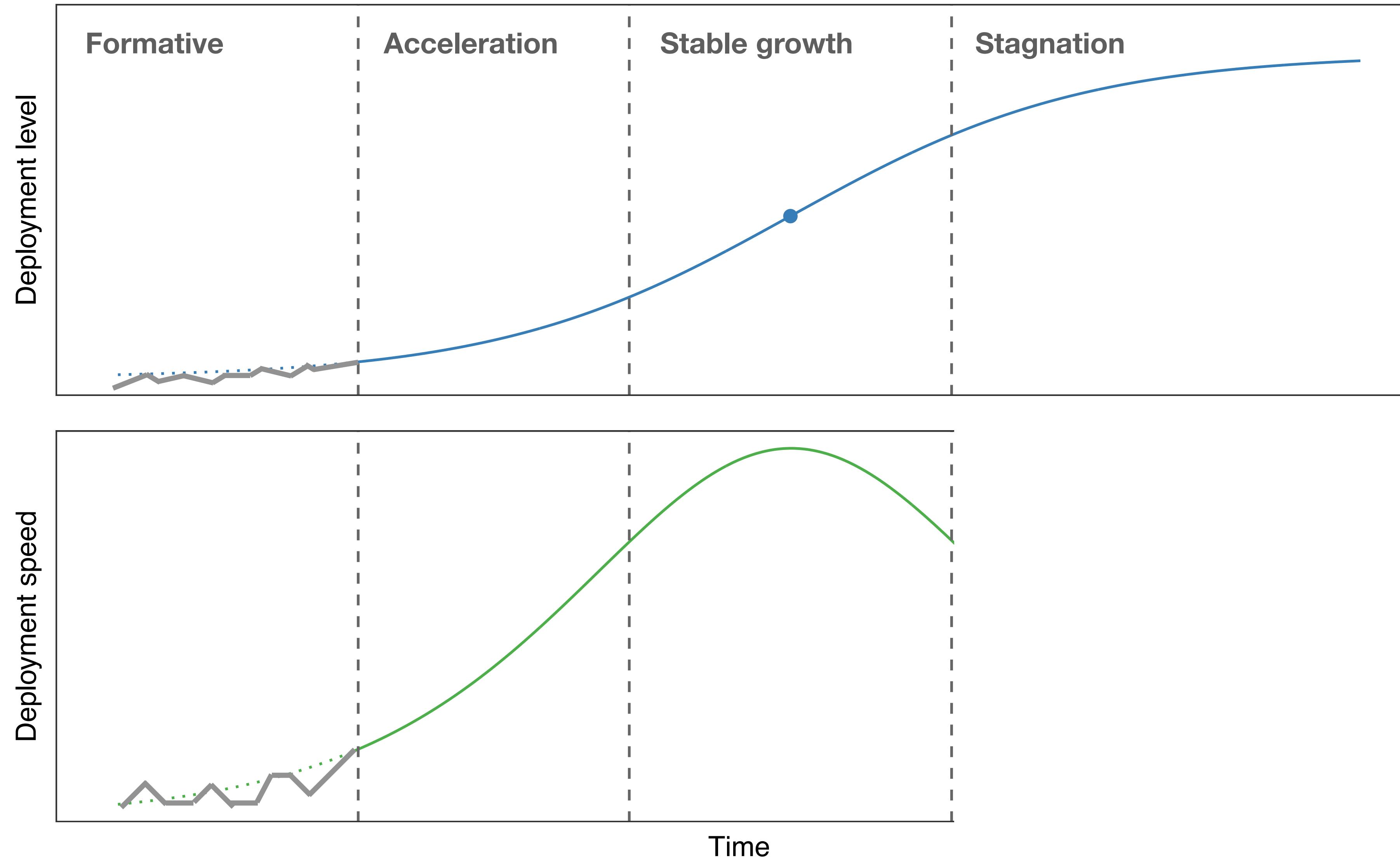
Mathematical expression of phases of growth



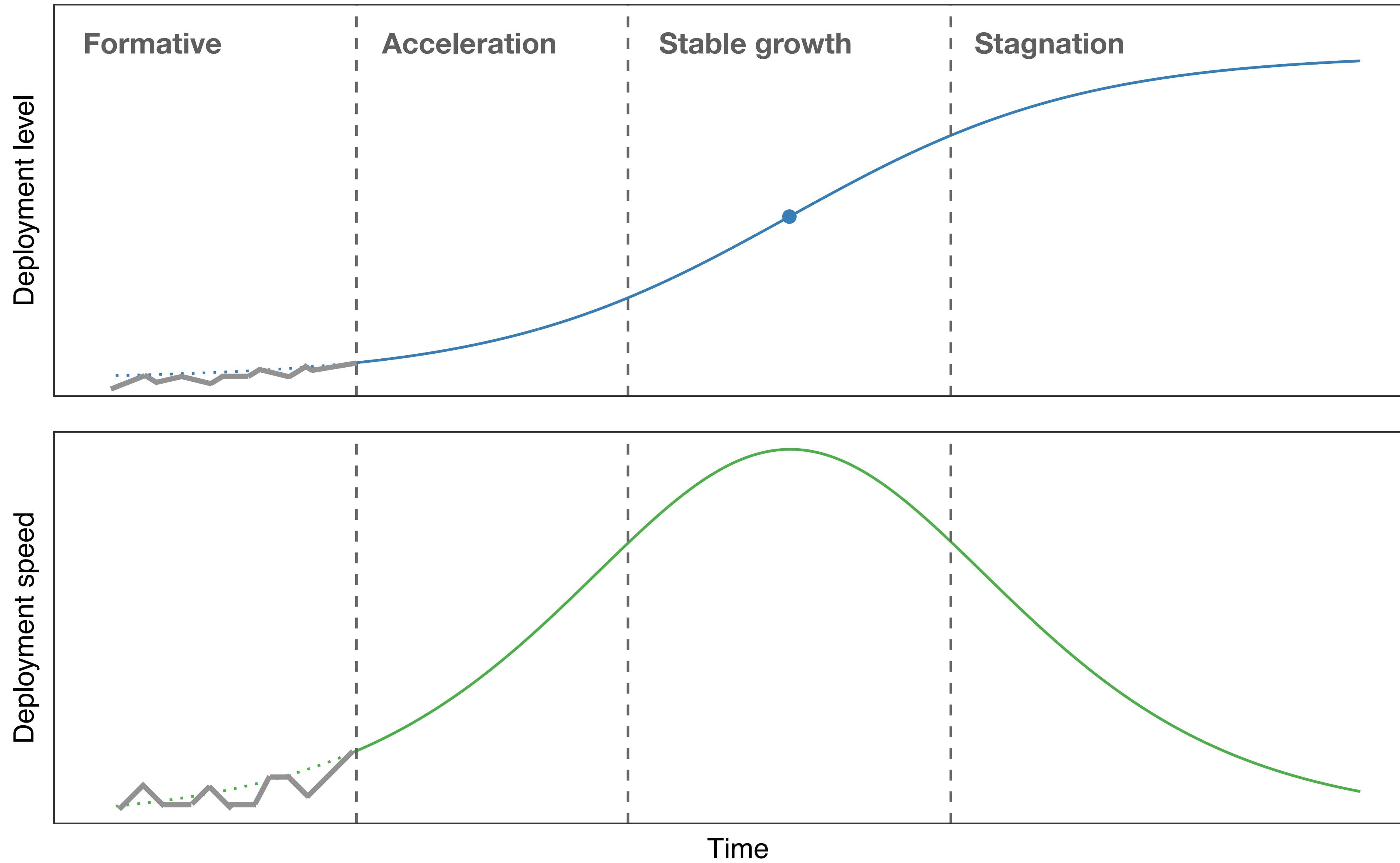
Mathematical expression of phases of growth



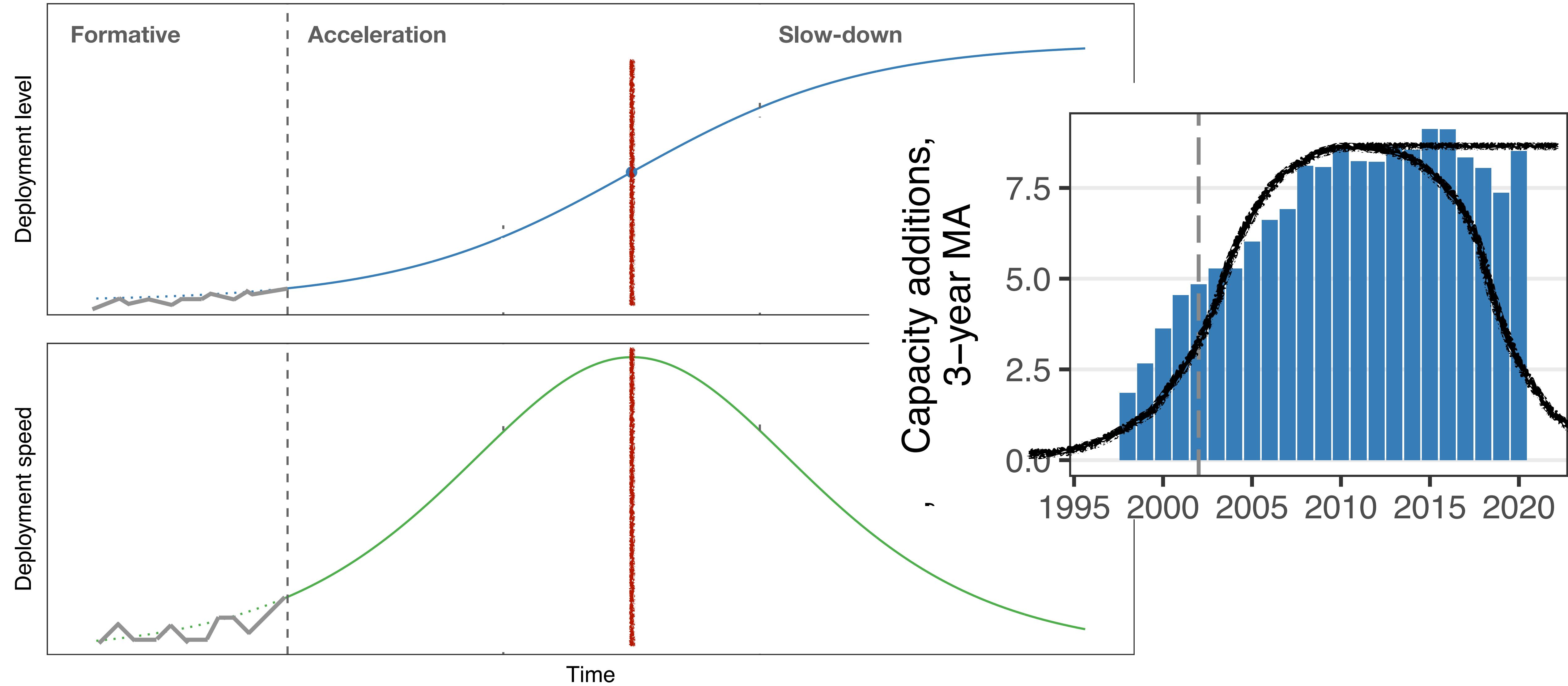
Mathematical expression of phases of growth



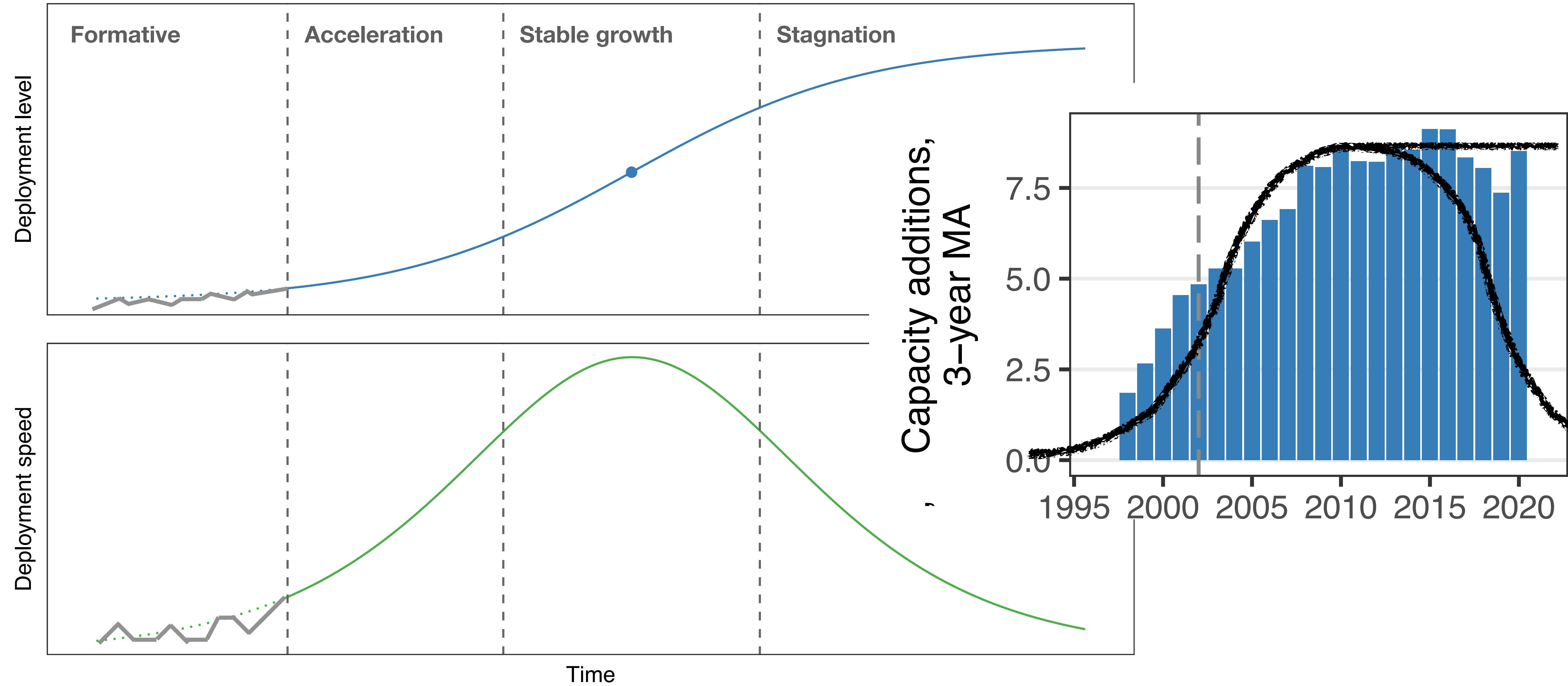
Mathematical expression of phases of growth



Missing the stable growth phase leads to bad projections



Missing the stable growth phase leads to bad projections



In-class exercise

- Four cases: electric vehicles | e-scooters | diesel cars | electric airplane
- Introduce the case –
 - Which phase of growth is the technology in?
 - What data and evidence did you consult?
- What would you look at to confirm your diagnosis if you had more time?