



Technological Change: Dealing with uncertainty and divergent futures

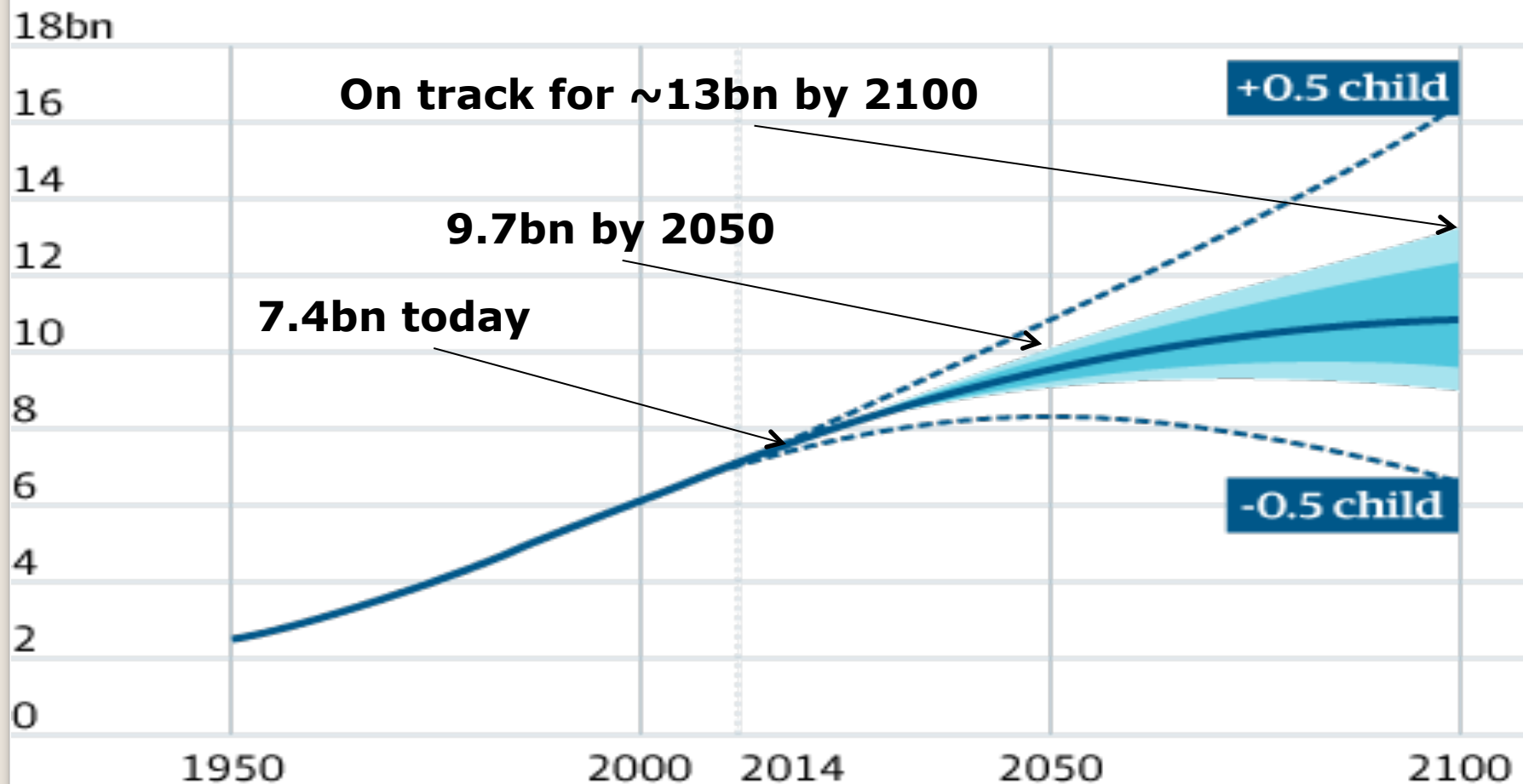


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World population projection

Total population, billions

— UN world population projection - - Impact of higher/lower fertility rate
■ 80% probability ■ 95% probability



On track for ~13bn by 2100

9.7bn by 2050

7.4bn today

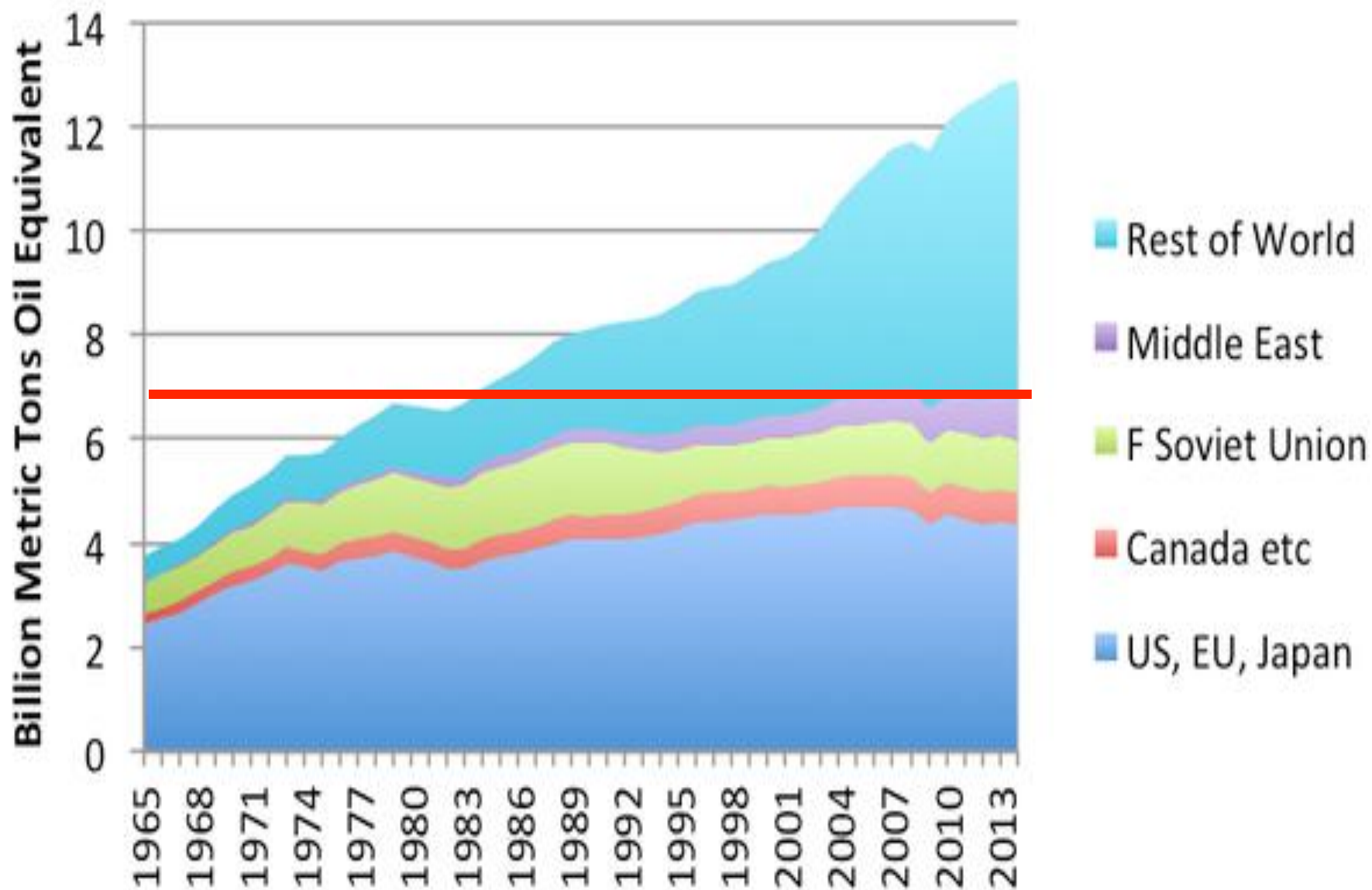
+0.5 child

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Energy demand

- 1973 (Arabic oil embargo): oil was 46% of global energy supply.
- 2014: Oil was 31% of global energy supply (coal 29%, natural gas 21%). Wind, solar and geothermal energy combined: just over 1%.
- More energy will be needed as population increases & economies develop.
- Energy demand will grow 55% 2005→2030, China and India will account for 50% of increase, developing countries 74%.
- Without major changes in policies and technologies, most of this energy will be sourced from coal and oil (by 2030 oil demand increase 37%, coal 73%).

World Energy Consumption by Part of World



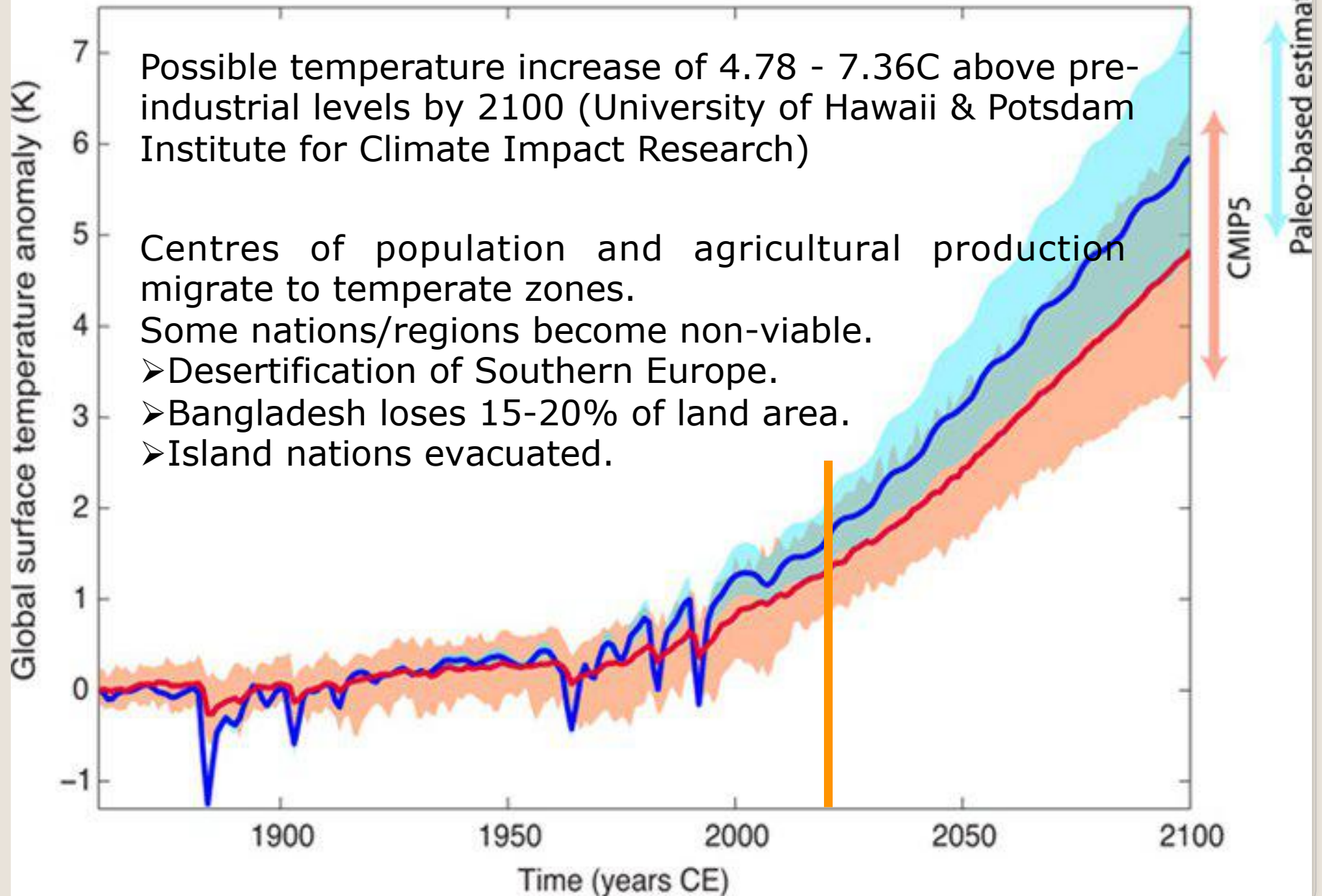
Consequence: rising carbon emissions

Possible temperature increase of 4.78 - 7.36°C above pre-industrial levels by 2100 (University of Hawaii & Potsdam Institute for Climate Impact Research)

Centres of population and agricultural production migrate to temperate zones.

Some nations/regions become non-viable.

- Desertification of Southern Europe.
- Bangladesh loses 15-20% of land area.
- Island nations evacuated.



Critical pressure points

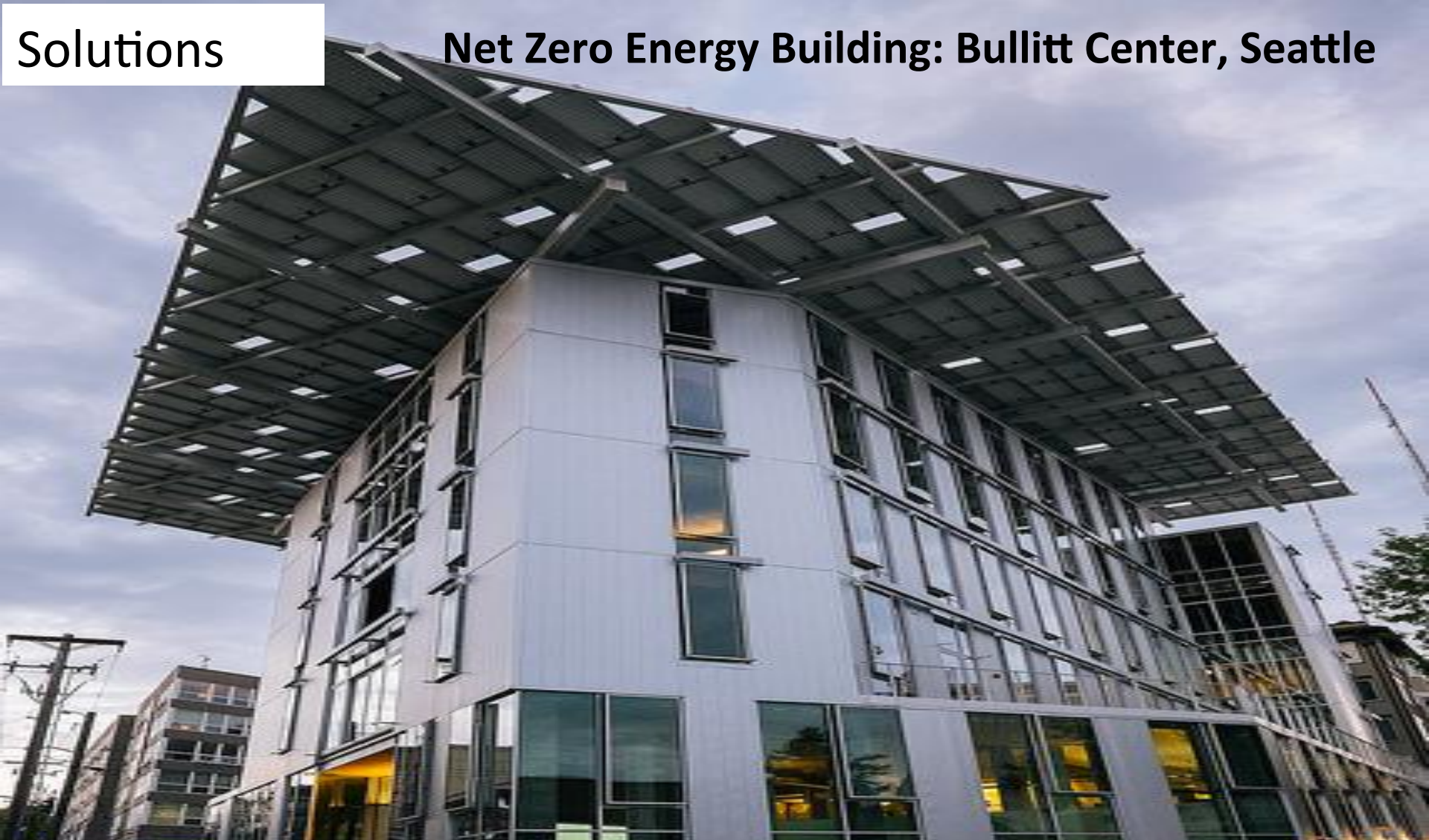
US National Intelligence Council: world demand for food, water, and energy will grow by approximately 35%, 40%, and 50% respectively by 2030.

UN: Half of population will have water shortages by 2030.

US/UK Strategic Assessments: climate change, water shortages will act as 'threat multipliers'; increased risk of conflict and terrorism.

Key areas for R&D:

- Increase efficiency (energy, water etc.). Closed-loop economies.
- Develop low carbon energy supplies. Energy storage, smart grids, renewable energy technologies (solar, wind turbines, sub-sea turbines etc.)
- New solutions for efficient urban living (food, energy, waste, transport etc.).



- Building uses approximately 230,000 KWH per year (typical office building of same size uses 1,077,000 KWH).
- 570 solar panels generate 230,000 KWH per year.
- If all new buildings like this: reduce world energy demand by 1/3rd.
- Focus on: new building technologies, smart grid, energy storage.

Solutions

By 2040: vehicles will be driverless

..but you won't
own one



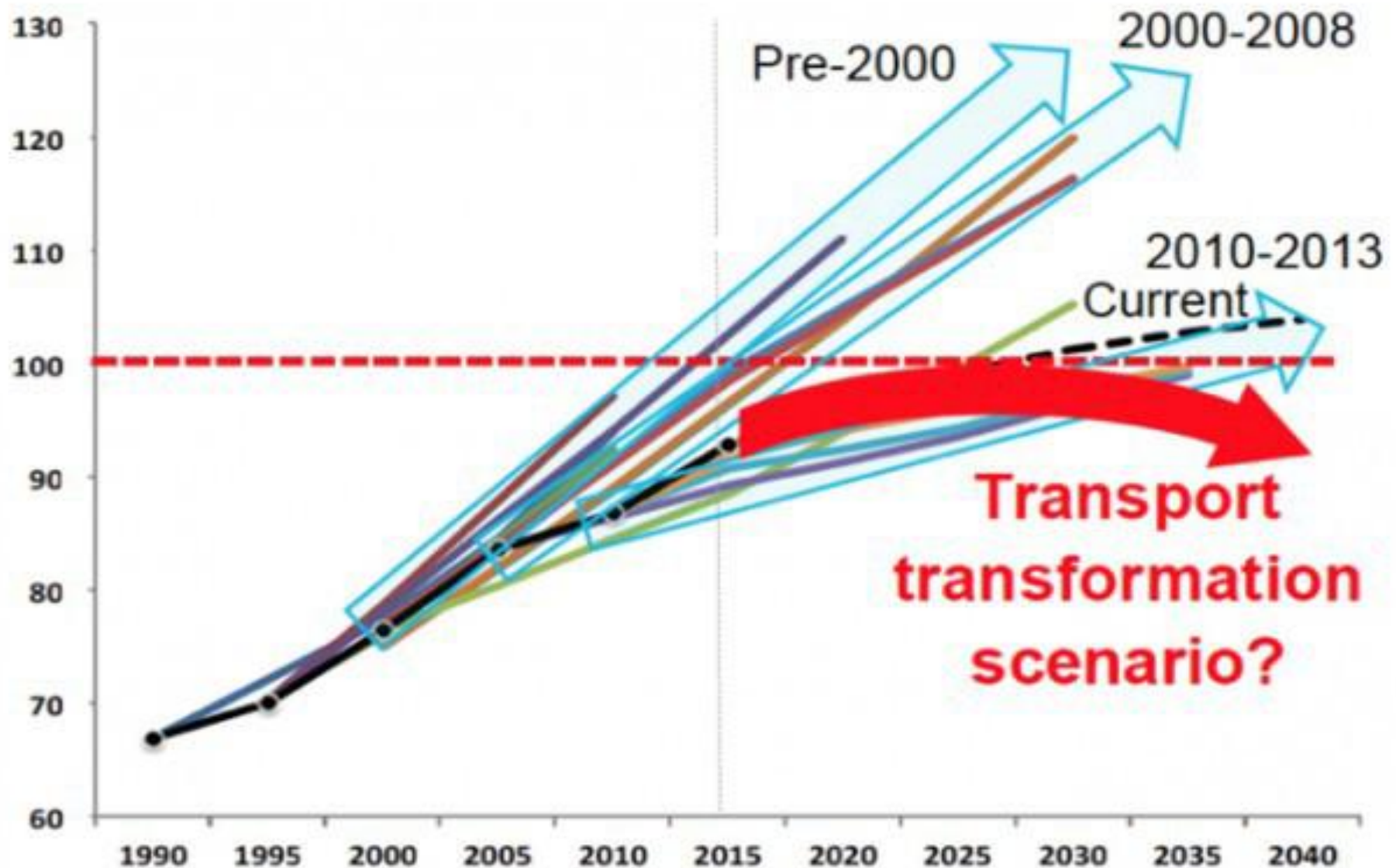
Most vehicles used 5% of time.

Uber model makes ownership redundant.

Will need <20% of the vehicle fleet.

Automated trucks will double capacity of roads & reduce cost per load by 75%: eight-fold improvement in price performance.

Declining Prospects for Oil



■ Forecasts in millions of barrels per day. Black line shows actual supply to date and 2014 IEA forecast. Source: IEA; BNEF

<https://thinkprogress.org/peak-oil-returns-why-demand-will-likely-peak-by-2030-86d6621c119c#.wajoebh70>

Conclusions

- Markedly divergent possible futures.
 - What skills, infrastructure, capacity will we need?
1. Look for 'no regrets' options – e.g. build smart grids, increase energy and resource-efficiency.
 2. Educational and training programs: must be multi-skilled, understand social, economic and engineering issues.

Thank you !

