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Generic technology and policy options for net-zero greenhouse gas emissions heavy industry

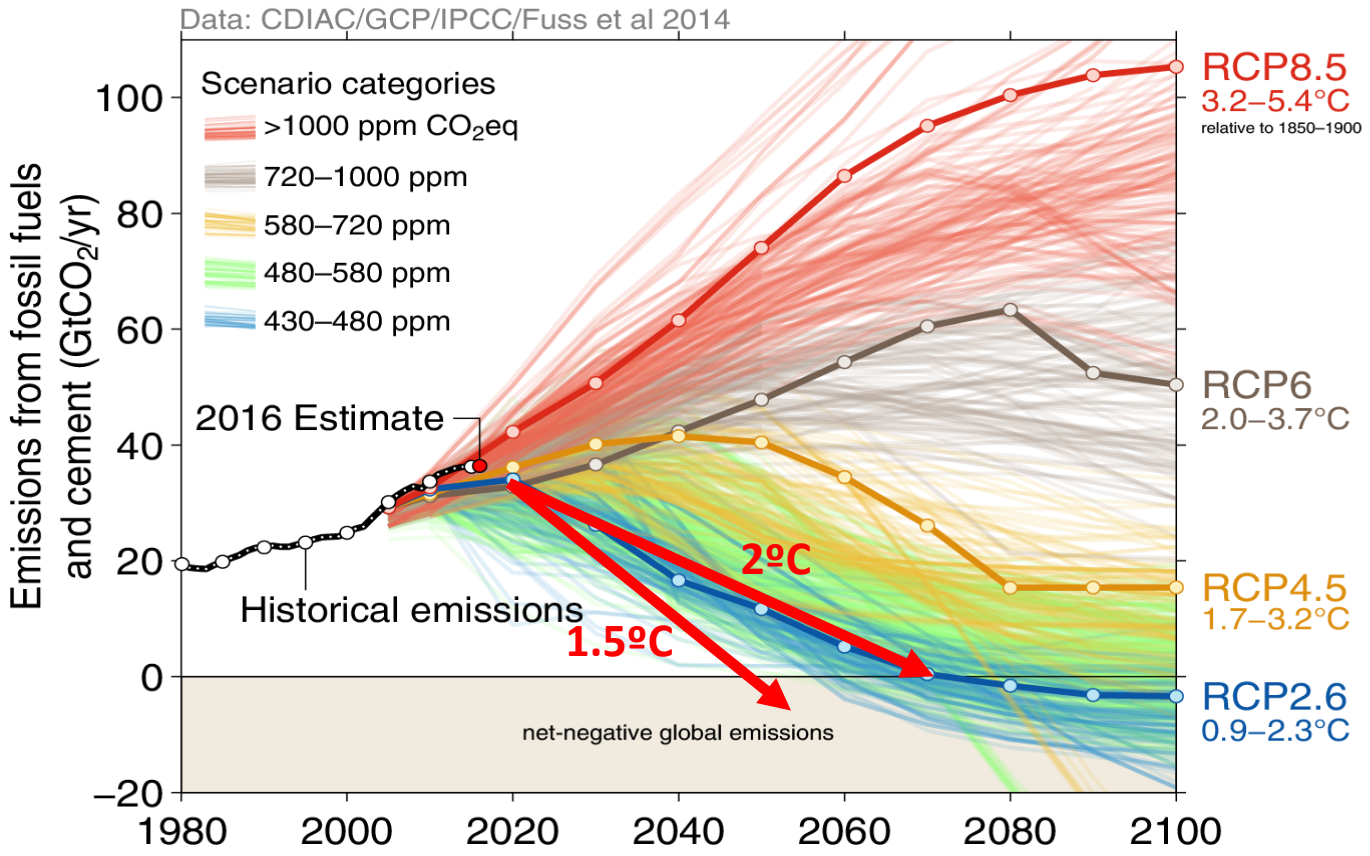
Dr. Chris Bataille

Associate Researcher / Adjunct Professor

Institute for Sustainable Development & International Relations (IDDRI.org)
(SciencesPo, Paris) / SFU (Vancouver)

chris.bataille@iddri.org

First things first:
the global carbon budget
and its implications for industrial mitigation opportunity costs



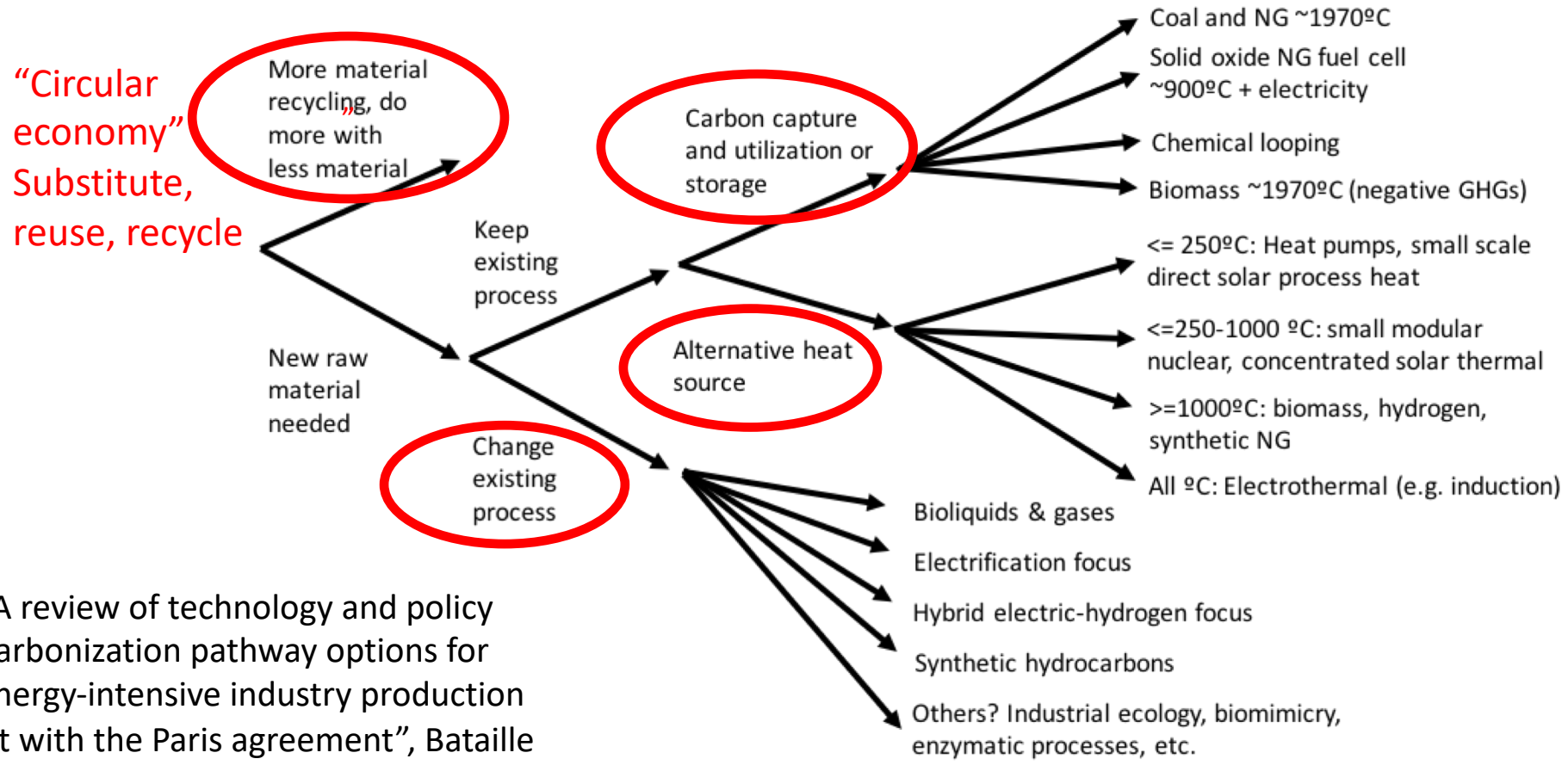
Global Carbon Project

Updated with data from Fuss (2016)

The big challenges of eliminating industrial greenhouse gas emissions to atmosphere

- We're maxing out the thermodynamic efficiency of new-builds with current tech
- The once through model for most material use (steel & aluminum as exceptions)
- Low (<=250C), medium (250-1000C) and high (>1000C) process heat for all industries
- Steel iron ore "deoxidization" CO_2 process emissions (& melting process heat)
- Cement lime calcination CO_2 process emissions (and process heat)
- Steam methane reforming CO_2 process emissions for hydrogen production for ammonia for fertilizers and other chemicals
- Non-ferrous metals & alloys (huge progress recently made in bauxite electrolysis)
- Making sure new materials aren't GHG combustion or process intense!
- Others?

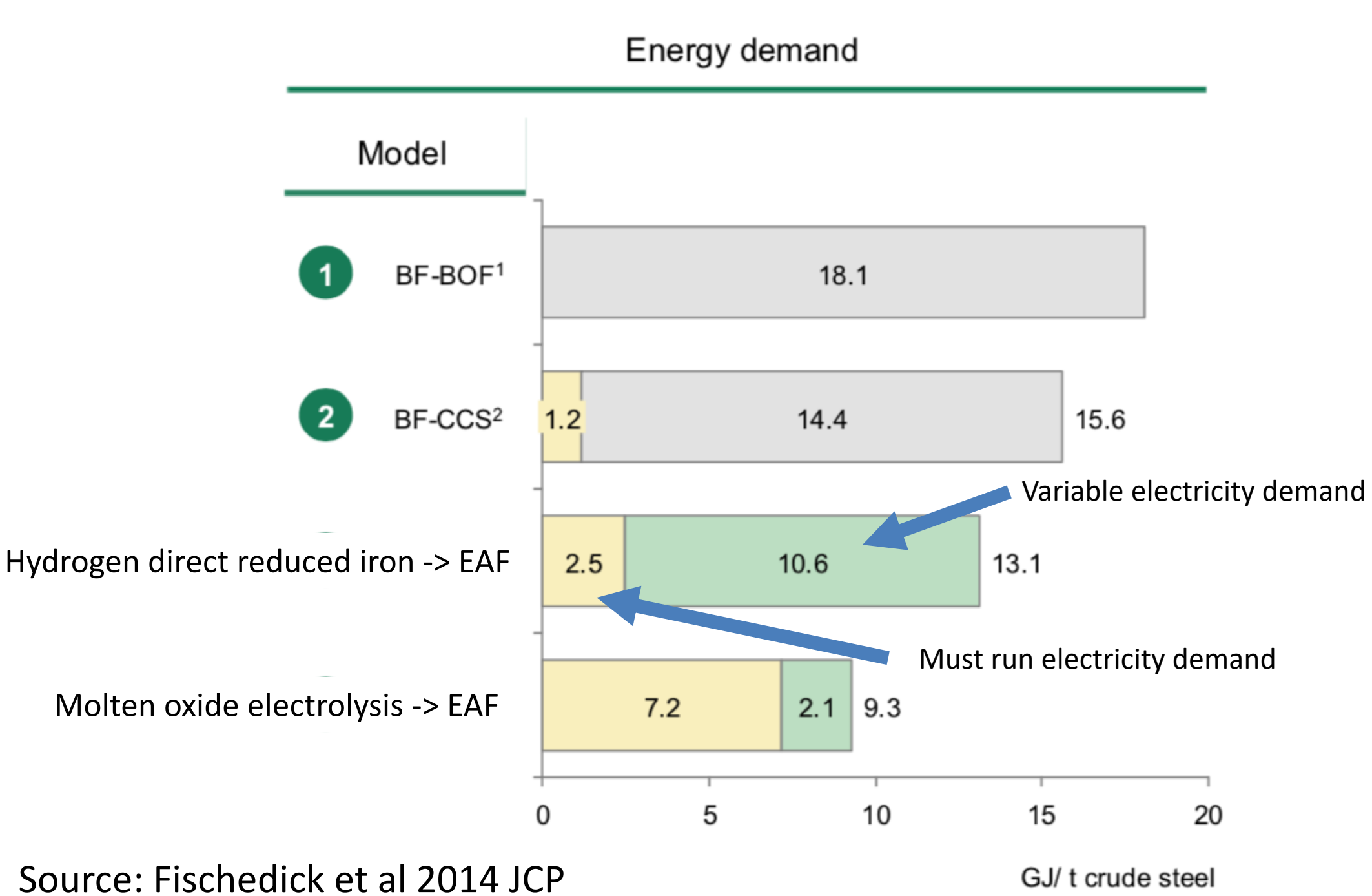
There are many ways to conceptualize it, but the upshot of several recent works is that there are emerging and near commercial options to decarbonize all industrial sectors



Source: "A review of technology and policy deep decarbonization pathway options for making energy-intensive industry production consistent with the Paris agreement", Bataille et al (2018) Journal of Cleaner Production

Dynamic questions that have to be addressed

1. *Circular economy*: First ”no-brainer”, but what happens if it isn’t easy or cheap?
2. *Electrification*: While this can be take as the second “no brainer”, instantaneous capacity constraints matter and could be very expensive (electric steel example).



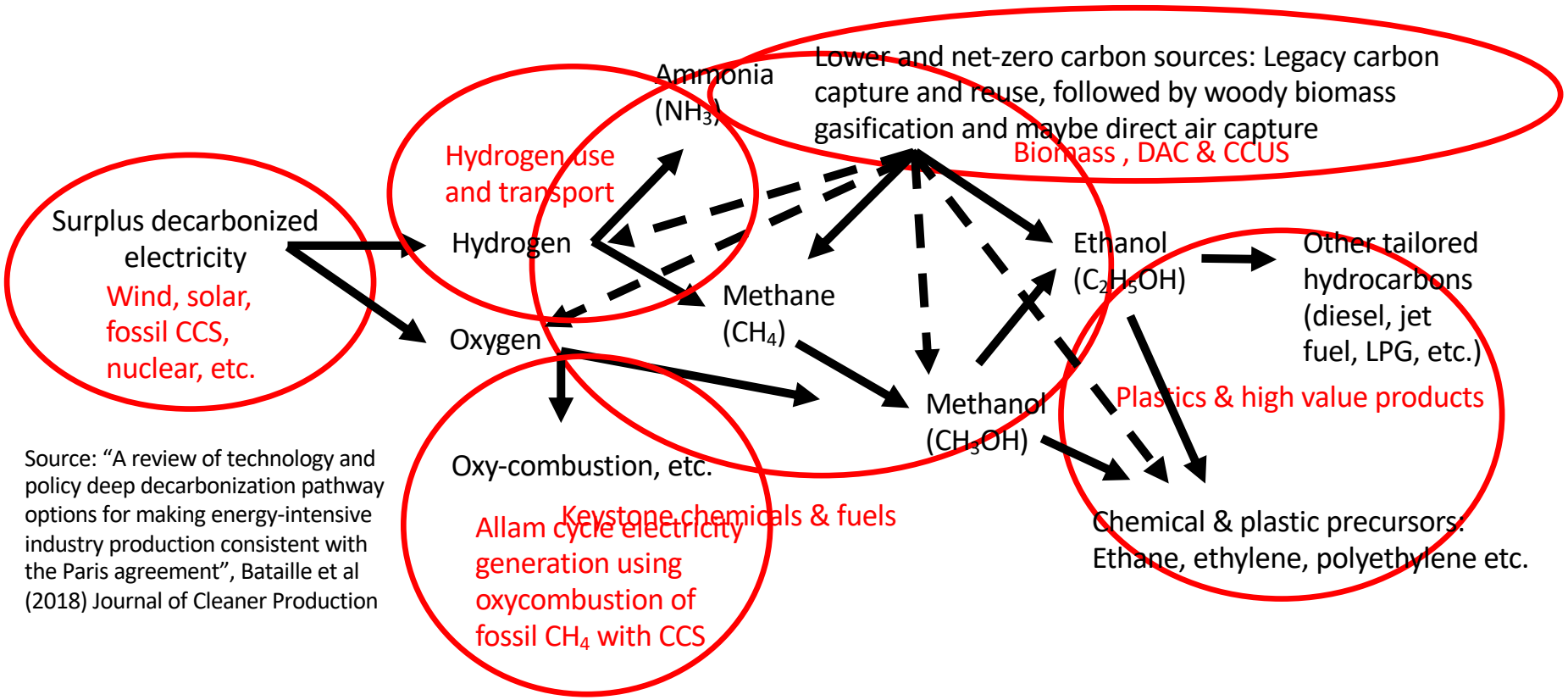
Source: Fischedick et al 2014 JCP

Dynamic questions that have to be addressed

1. *Circular economy*: First ”no-brainer”, but what happens if it isn’t easy or cheap?
2. *Electrification*: While this can be take as the second “no brainer”, instantaneous capacity constraints matter and could be very expensive (electric steel example).
3. *Carbon capture, utilization, storage:* What happens if CCS reservoirs, CCUS opportunities in a given region are limited?
4. *Alternative heat sources:* Enough in a given region, globally with trade?
5. *And what about all the long lived legacy facilities?*
6. *Can we build situation specific hybrids to solve for all of the above?*

- Upshot: We need infrastructure & policy robust to all possibilities, that helps guide us through to local solutions

While electrification is the default, we have to face the non or very expensively electrifiables. Can they be addressed with a hybrid electricity, hydrogen, & synthetic hydrocarbon transition path?



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Candidate technological “moonshots”: A potentially diversified portfolio of technology tools

- Alternative cement chemistries combined with “only where necessary” design;
- High temperature heat pumps;
- Electrothermal technologies;
- Electrolytic smelting
- Electric virgin steel production (DRI hydrogen EAF or molten oxide electrolysis EAF);
- Lower cost and more efficient electrolysis for hydrogen (alkaline->PEM/SOFC, cost /2, efficiency X2?);
- Post-combustion and direct-from-air CO_2 capture;
- Woody biomass pyrolysis / gasification to make renewable methane;
- Solid oxide fuel cells (SOFC); Others?

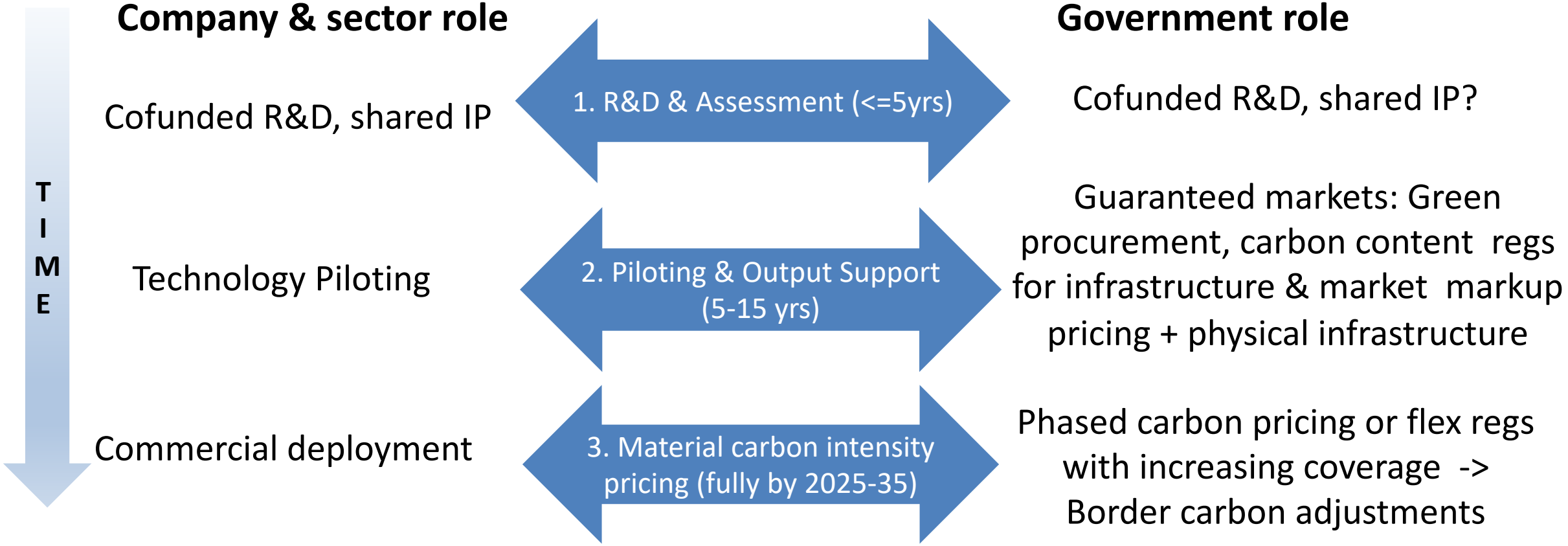
Simple carbon pricing and / or regulations are not enough: The challenges are more than technological

- While emerging tech exists, industrial firms will underinvest because:
  - of low profit margins
  - competitive; they can’t pass on costs without losing market share
  - CAPEX is focussed and upfront
  - they can't capture the benefits of innovation
  - few co-benefits, unlike transport and electricity
  - the kicker; ***there is no market for more expensive low GHG materials***
- Policy for heavy industry needs to target these challenges directly:

The combined pillars/strategies of a generalized transition plan & "local solution finding" policy package

- An initial **policy commitment** to transition into net-zero GHG industry
- Where possible **reduce demand, substitute, reuse and recycle**
- A stakeholder pathways process including all key players to assess strategic & technological options, competitive advantages, uncertainties & **build a full transition plan**
- Business models to share innovation risk across firms, govt. & consumers; create markets w/ green procurement, content regs, guaranteed pricing & output subsidies. *IP sharing!*
- Multistage exposure of all sectors to **full GHG pricing** with protection for competitiveness, e.g. border carbon adjustments in transition
- **Supporting institutions**: oversite to gauge progress and adjust policy; electricity sector reform; electricity & H_2 infrastructure; lifecycle GHG accounting; education; regulatory environment, inc. liability insurance recs.

The roles of companies and government
(from a current working / under submission paper)

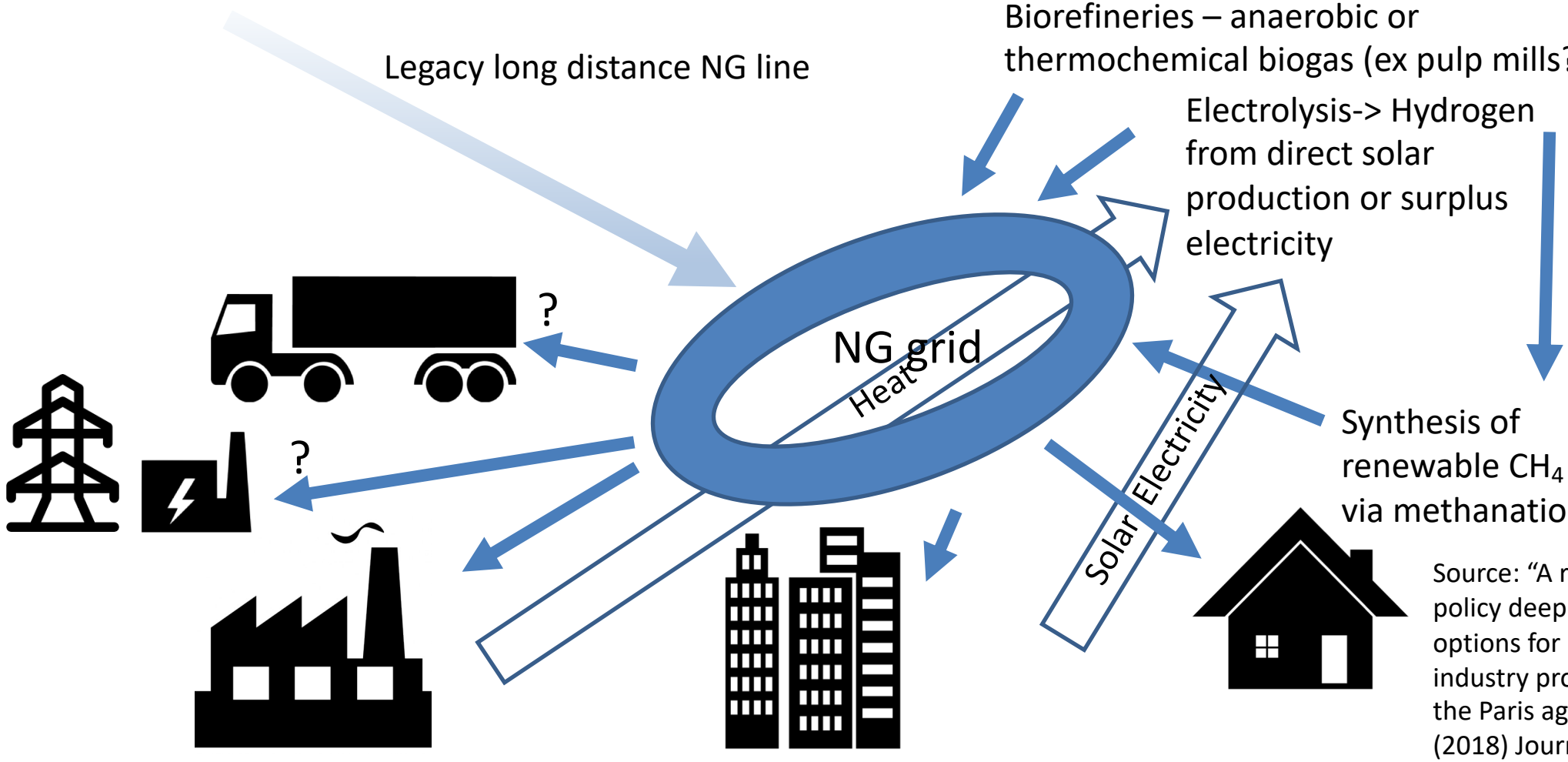


Source: Bataille, C. and Stiebert, S. June 2018. The transition toward very low carbon heavy industry in the Canadian context: Detailed technical and policy analysis and recommendations for the iron & steel, chemicals, forestry products & packaging, and base metal mining & processing sectors. ResearchGate: DOI: 10.13140/RG.2.2.30872.29447

Conclusion

- The technology and strategies exist to transition the heavy industry sector to net-zero emissions but they need R&D, piloting & market support, and eventually full economy market based regulations or carbon pricing.
- We need “solution finding” policy packages, a risk robust portfolio approach to strategies and technologies and policy packages to implement them, built on stakeholder processes that include everyone needed to implement them and who could block the process, reflecting national and regional capacities, politics, resources, and other key circumstances.
- For questions: chris.bataille@iddri.org, DM @bataille_chris

Transition and transformation: While new should be net-zero based by the late 2030s, the NG transmission grid *could* be key to transition of legacy buildings, industry and load following NG electricity generation



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Backing up a bit, what does net-zero deep decarbonization mean? The DDPP pillars

- Efficiency (min 50% improvement)
- Decarbonization of energy carriers (electricity, hydrogen, biofuels, synthetic hydrocarbons (e.g.NG))
- Switching to decarbonized energy carriers & energy storage
- Direct emissions reduction
  - Management of all land in consideration of carbon emissions
  - CCS to eventually allow non-land use net-negative emissions
- Domestic and international institutions to carry out policy, allow emissions trading, and conduct shared R&D projects