

Techno-economic analysis on modularisation and complex project management

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Can we have on time and budget “Nuclear reactors projects”?

Flamanville costs up €2 billion

04 December 2012

France's first EPR is still on schedule for operation in 2016 but factors including new regulatory requirements and lessons learned from Fukushima have pushed the calculated costs of the project up.

the guardian
website of the year

home > business economics banking retail markets eurozone

EDF Energy

EDF's Hinkley Point nuclear nightmare adds to company's woes

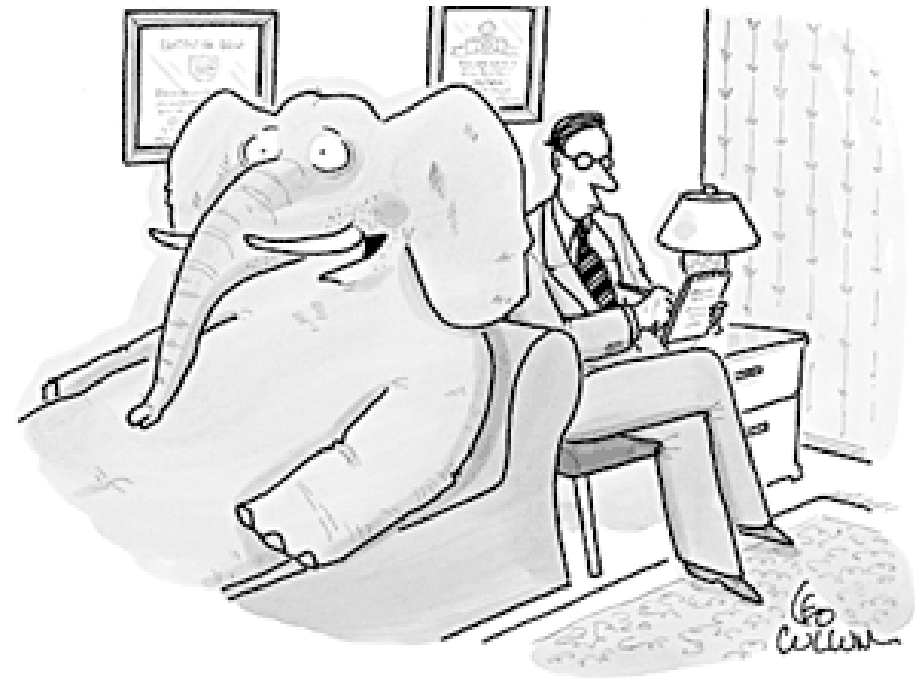
Debts, boardroom disputes, delayed nuclear projects - the many troubles of the French-owned power company

06.08.2013_No195 / News in Brief

Slovak Government Increases Budget For Mochovce-3 and -4

Plans & Construction

6 Aug (NucNet): The Slovak government has approved an increase in the cost of reactor units of 260 million euros (EUR) (344 million US dollars).



“I'm right there in the room, and no one even acknowledges me.”

UPDATED: SCANA, Santee Cooper Abandon V.C. Summer AP1000 Nuclear Units, Citing High Costs

07/31/2017 | Sonal Patel

THE WALL STREET JOURNAL

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MH370 Breakthrough Prompts Anger and Disbelief in China

Andrzej Duda Sworn In as Poland's New President

Brazil Leader's Approval Rating Falls

MIDDLE EAST CROSSROADS Iraq's Baathists: From ISIS Allies ...

China's First Advanced Nuclear Reactor Faces More Delays

Start-Up Now Unlikely Until 2016 at the Earliest

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The same old story...

Projected and Actual Construction Costs for Nuclear Power Plants (USA)

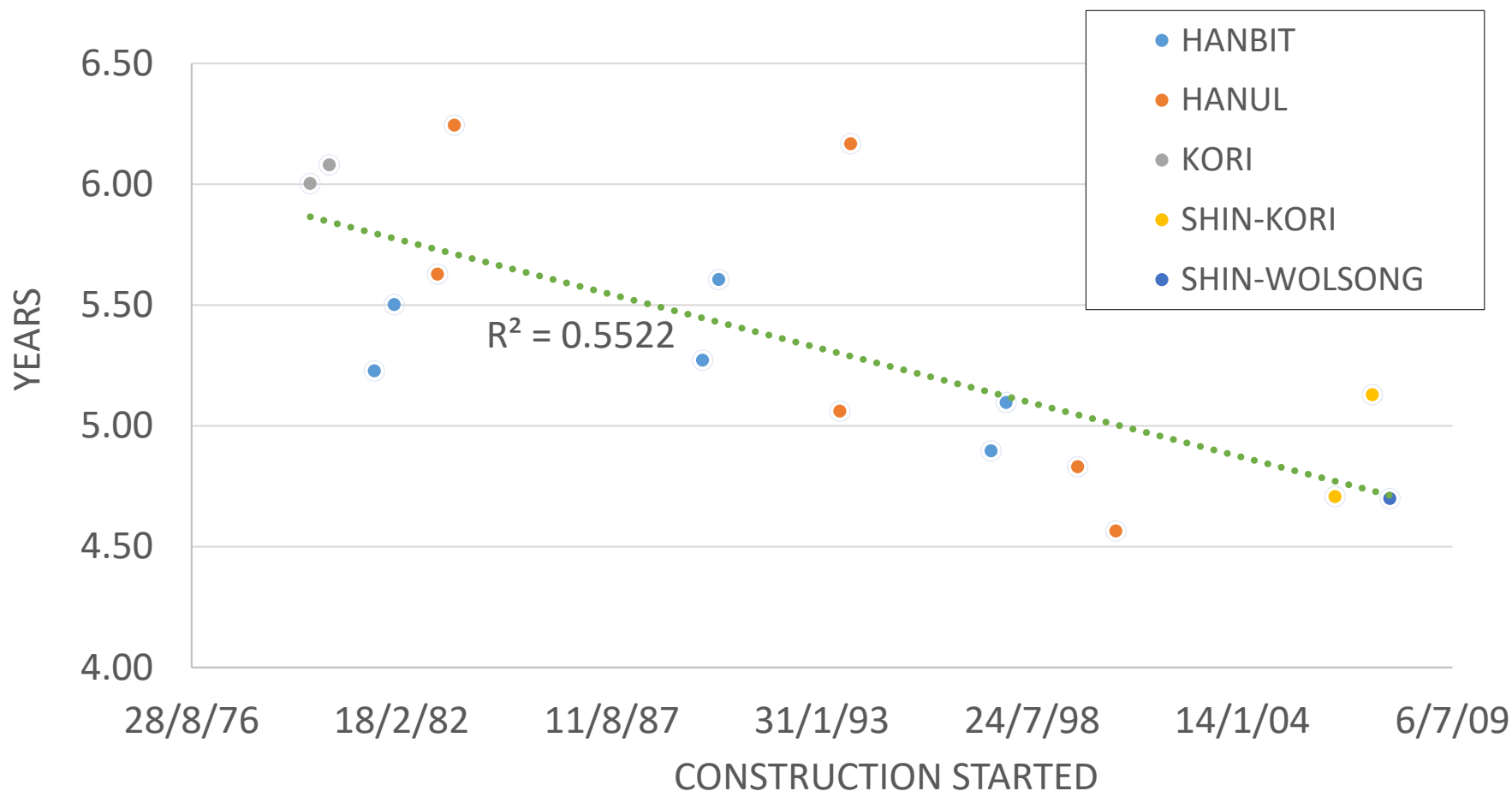
Construction Starts	Average Overnight Costs ^a			
	Year Initiated	Utilities' Projections (Thousands of dollars per MW)	Actual (Thousands of dollars per MW)	Overrun (Percent)
Number of Plants ^b				
1966 to 1967	11	612	1,279	109
1968 to 1969	26	741	2,180	194
1970 to 1971	12	829	2,889	248
1972 to 1973	7	1,220	3,882	218
1974 to 1975	14	1,263	4,817	281
1976 to 1977	5	1,630	4,377	169
Overall Average	13	938	2,959	207

Source: Congressional Budget Office (CBO) based on data from Energy Information Administration, *An Analysis of Nuclear Power Plant Construction Costs*, Technical Report DOE/EIA-0485 (January 1, 1978).

Actual = budget X 3

Can we have on time and budget “Nuclear reactors projects”? YES!

CONSTRUCTION TIME FOR THE STANDARD 1 GW KOREAN PWR



Megaprojects – Some literature

Sovacool, Benjamin K., Daniel Nugent, and Alex Gilbert. "Construction cost overruns and electricity infrastructure: an unavoidable risk?" *The Electricity Journal* 27.4 (2014): 112-120.

"401 power plant and transmission projects in 57 countries [...] with only 39 projects across the entire sample experiencing no cost overrun"

Sovacool, Benjamin K., Alex Gilbert, and Daniel Nugent. "An international comparative assessment of construction cost overruns for electricity infrastructure." *Energy Research & Social Science* 3 (2014): 152-160.

"Hydroelectric dams and nuclear reactors have the greatest amount and frequency of cost overruns, even when normalized to overrun per installed MW [...] solar and wind projects seem to present the least construction risk."

Sovacool, Benjamin K., Alex Gilbert, and Daniel Nugent. "Risk, innovation, electricity infrastructure and construction cost overruns: Testing six hypotheses." *Energy* 74 (2014): 906-917.

*"H1 Bigger is bad
H5 - small is beautiful"*

"the propensity of big capital investments to systematically deliver poor outcomes"

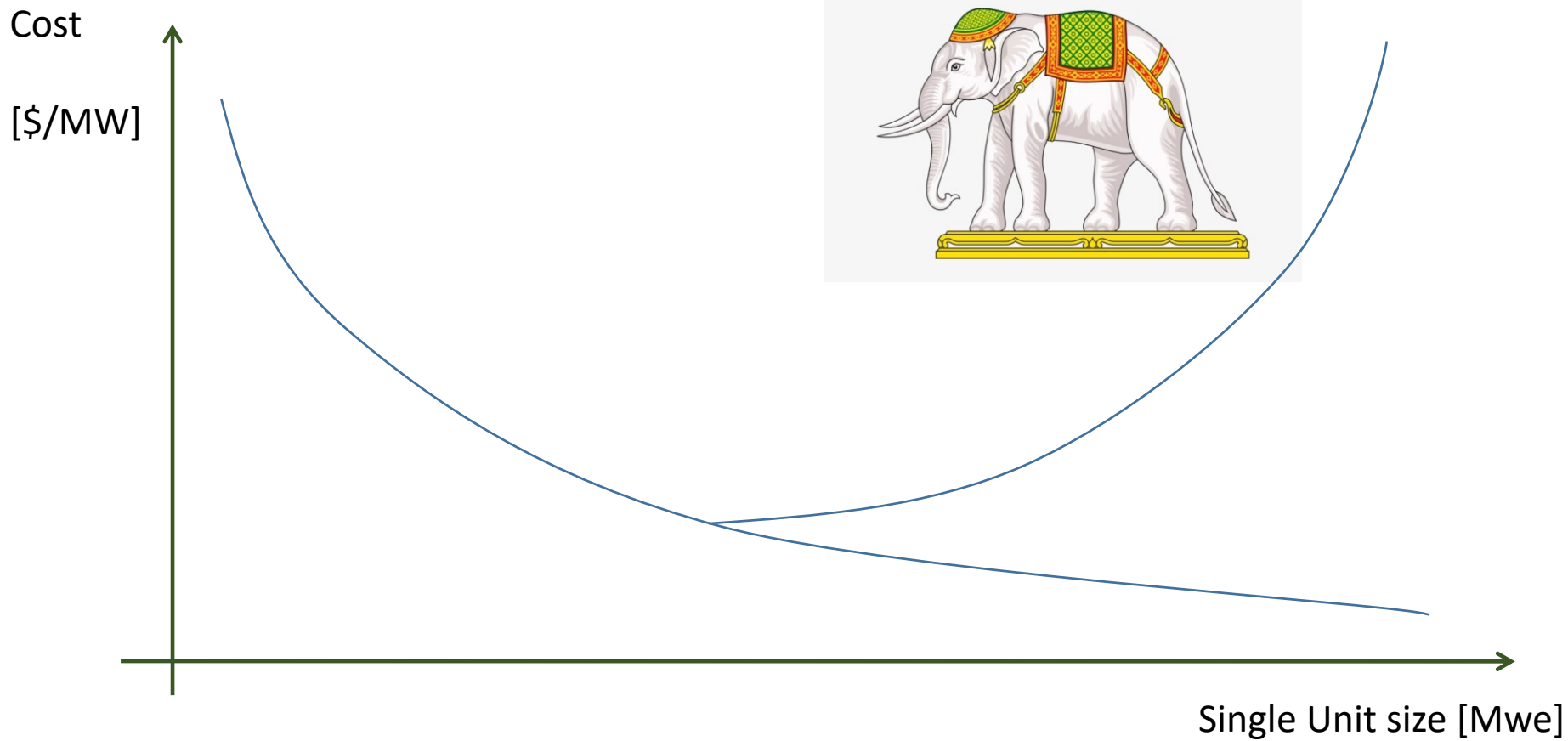
Ansar, Atif, et al. "Big is Fragile: An Attempt at Theorizing Scale." (2016).

Big here is intended as

- Physically Unique, uncommon, expensive, long construction
- With a unique new team of stakeholders

above and beyond their economies of scale and scope."

Misunderstanding about economy of scale



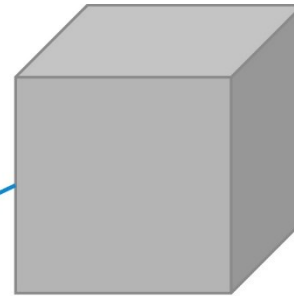
Economy of multiples



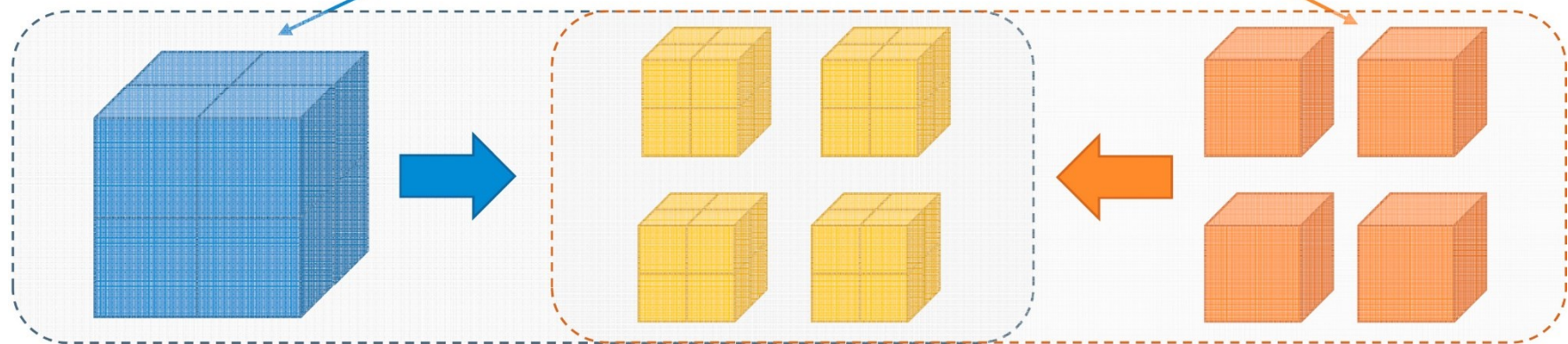
For the same power, the smaller the plant, more units are built

We need words to understand

Mignacca, B., Locatelli, G., & Velenturf, A. (2020). Modularisation as enabler of circular economy in energy infrastructure. *Energy policy*, 139, 111371.



Monolithic plant: A plant constructed in the field without extensive use of modules; also referred to as a stick-built plant



Modularisation: Process of converting the design and construction of a monolithic or stick-built plant to facilitate factory fabrication of modules for shipment and installation in the field as complete assemblies

Modularity: A standard unit assembled onsite from factory produced modules, usually of smaller capacity than a monolithic plant, to maximize the benefit from modularity effects

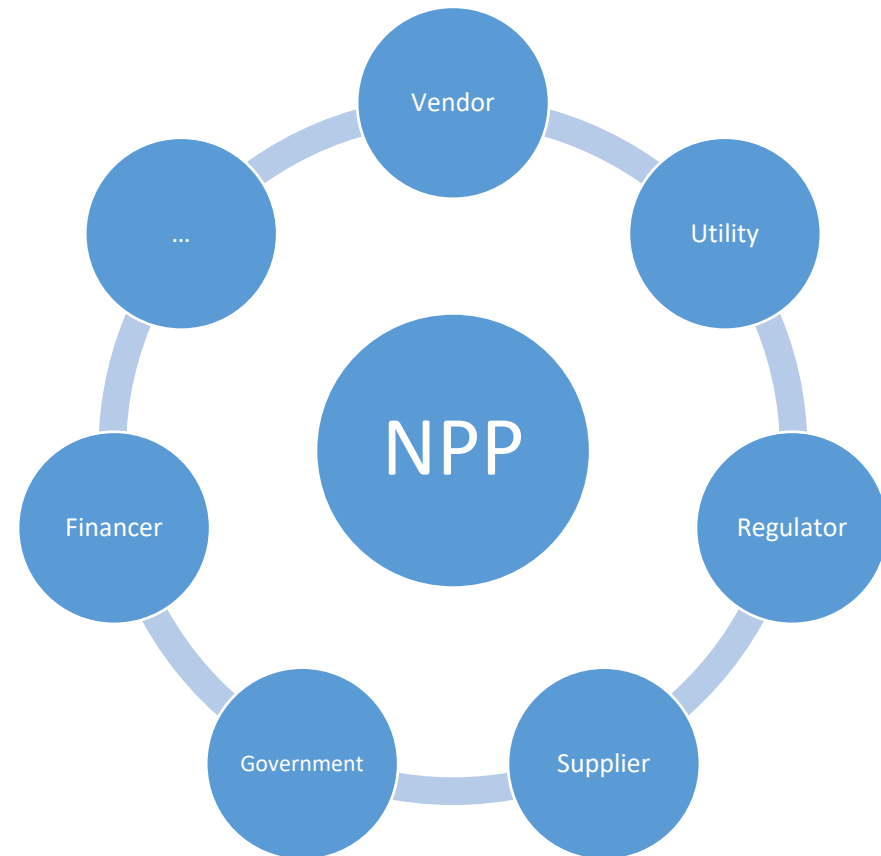
Pure Standardisation: the delivery of (nearly) identical stick-built power plants form a consistent set of stakeholders in the project delivery chain

The two sides of standardisation

Physical standardisation



Project delivery chain



What's about risk?

- FOAK cost unknown



True for LR and SMR, but the scale is dramatically different



- Exogenous (construction time related)

- Exchange rates
- Interests escalation
- Legislation changes (Chernobyl / Fukushima events)
- COVID
- ...



SMR shorter construction time

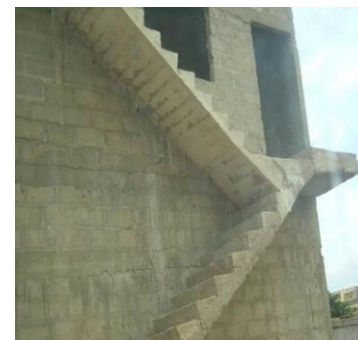


- Endogenous











- Design mistakes/uncertainties
- Suppliers mistakes
- Mistakes in the construction
- ...



Fostered industrial learning (Korean Like)



Key ideas

	Stand alone Large	Several “right” SMR
<ul style="list-style-type: none"> Benchmark previous projects 		
<ul style="list-style-type: none"> Start from a completed design! Remember the Rickover Effect <ul style="list-style-type: none"> Requires an immense amount of development on apparently trivial items; Takes a long time to build because of its engineering development problems Reworks, mistakes in constructions, change requests 		
<ul style="list-style-type: none"> Develop stakeholders accountability <ul style="list-style-type: none"> “you won’t get the next projects if you don’t perform well on this one” Create long term collaboration between stakeholders 		
<ul style="list-style-type: none"> Foster the “economy of multiples” <ul style="list-style-type: none"> Learning for all the stakeholders involved Multiple units in the single site 		
<ul style="list-style-type: none"> Economy of scale <ul style="list-style-type: none"> Don’t go to small, don’t go to big! 		

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NEA Workshop on Advanced Construction and Manufacturing Methodologies for New Nuclear Build

Session 3: Improving constructability with small, modular and innovative nuclear designs

Rethinking Nuclear Deployment for Zero-Carbon Energy at Scale – A Vision for 2050

Andrew Sowder, Sr. Technical Executive
Advanced Nuclear Technology Program

March 17, 2022





Rethinking Deployment Scenarios for Advanced Reactors

Scalable Nuclear Energy for Zero-Carbon Synthetic Fuels and Products

Technical Brief — Advanced Nuclear Technology



3002018348

December 2021

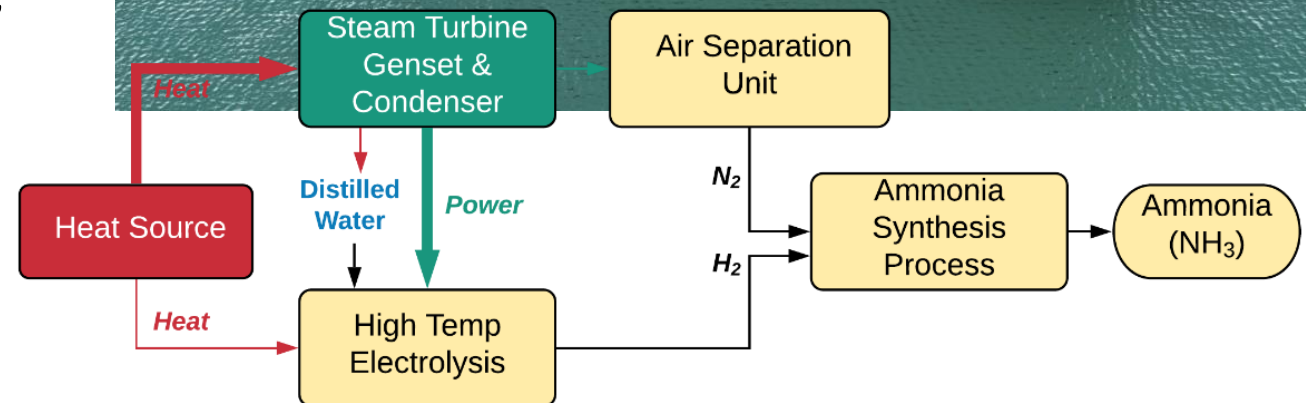
<https://www.epri.com/research/products/00000003002018348>

Rethinking Nuclear Deployment: Key Study Tenets

- Move to fabricating entire standardized plant/platform in a fully-engineered environment – *a la* large modern shipyards.
- Deliver plant/platform to point of use via marine conveyance.
- Produce storable, conveyable, drop-in substitutes for fossil fuels in hard-to-decarbonize sectors via floating production, storage, offloading (FPSO) model.
- Supply zero-carbon synthetic fuels and products to market at competitive prices.

One of four scenarios: competitive carbon neutral ammonia for commercial shipping

- conveys 90% of global trade
- difficult to decarbonize



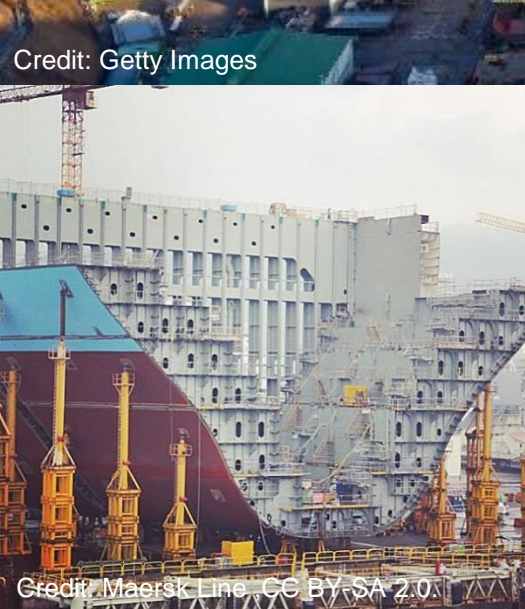
Is this feasible?



Credit: Getty Images



Credit: U.S. Navy



Credit: Maersk Line, CC BY-SA 2.0

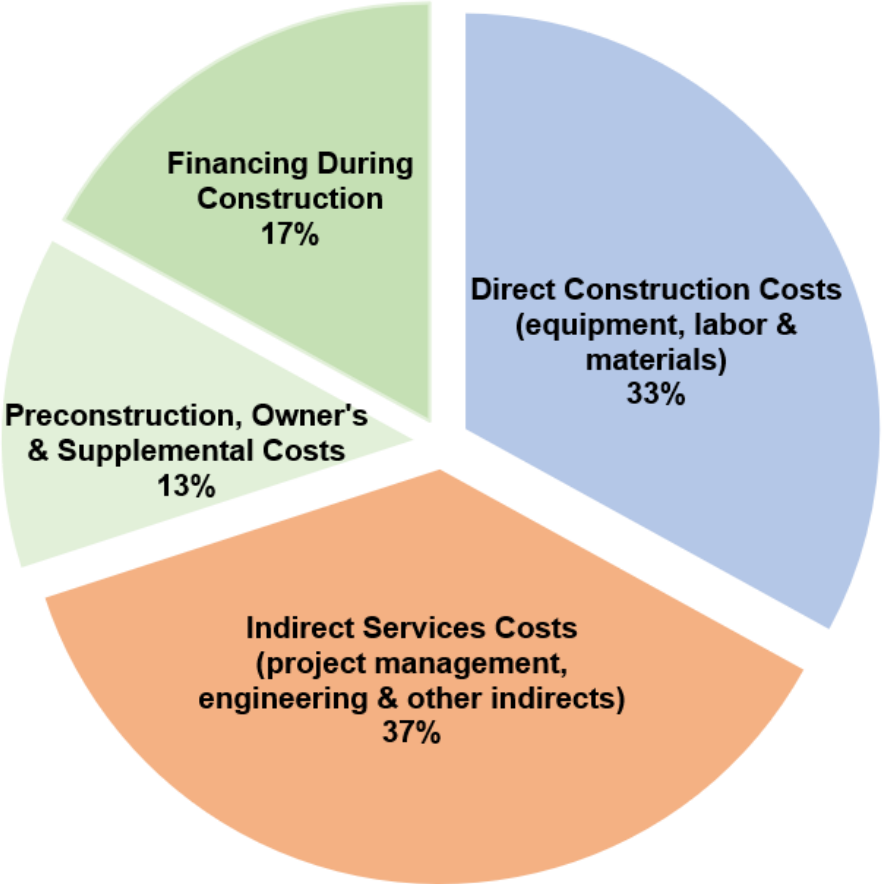


Credit: Getty Images



Credit: Getty Images

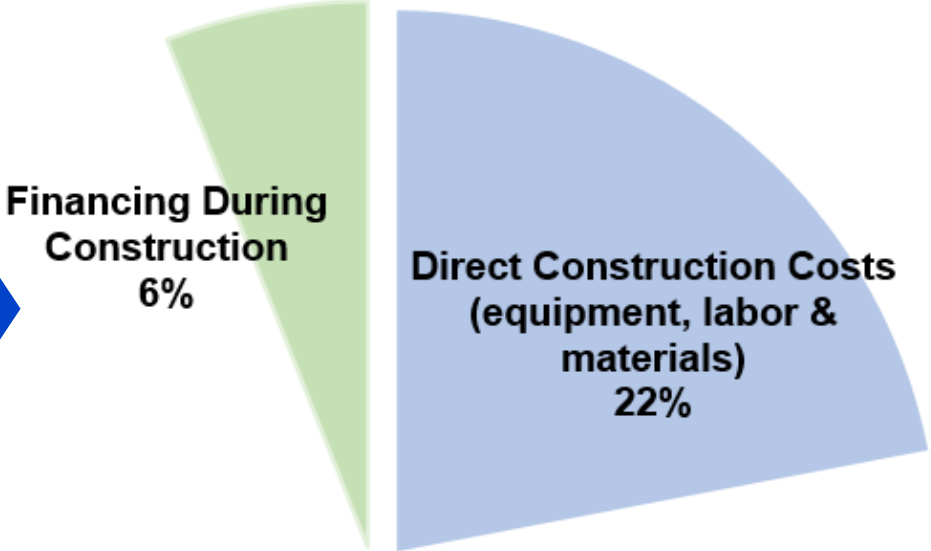
What could transformation of nuclear construction do to costs?



\$6800/kWe

Reference GWe-class LWR

(Source: EON/EIRP, 2018)



72% Net Cost Reduction =

\$1900/kWe

Equivalent plant via serial production

Indicative economics look promising.

Product	Benchmark Price (without carbon abatement)	Levelized Zero- Carbon Product Cost	Units
Jet A (Kerosene-Type Jet Fuel)	94	82	USD/bbl
Ammonia (NH ₃)	200	230 - 290	USD/tonne
Hydrogen	0.7 – 1.6	0.9	USD/kg
Electricity	68.3 – 185 ^a 102 – 334 ^b	43	USD/MWh
Desalinated Water	0.64 – 2.86	1.3	USD/m ³

^a OECD industrial electricity price range for 2019

^b OECD residential electricity price range for 2019



Together...Shaping the Future of Energy®



The UK Government's 'Platform' approach to industrialised construction

Jaimie Johnston MBE

Director, Head of Global Systems,
Bryden Wood

Platform Design Lead,
Construction Innovation Hub



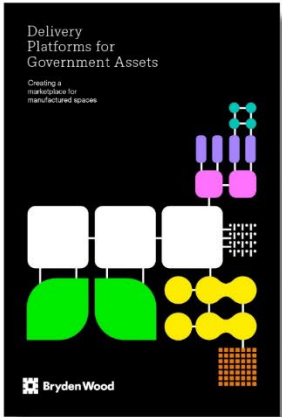
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Common challenges across construction

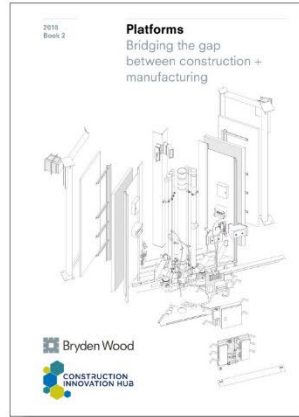
- Safety (often while delivering assets on complex live sites);
- Sustainability (in the broadest sense – environmental, economic, social...);
- Future flexibility (with fast evolving processes / technology);
- Cost (capex and whole life);
- Speed of delivery (on site);
- Ability to delay capital spend to the 'last responsible moment';
- Innovation in design and delivery (leveraging wider industry shift);
- What does the world look like post COVID-19?



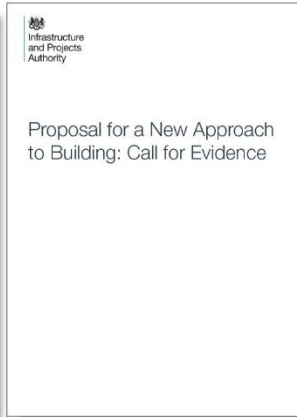
Delivery Platforms for Government Assets



Platforms: Bridging the gap between construction + manufacturing



Proposal for a New Approach to Building



'We will use a set of digitally designed components across multiple types of built asset... a single component could be used as part of a school, hospital, prison building or station.'

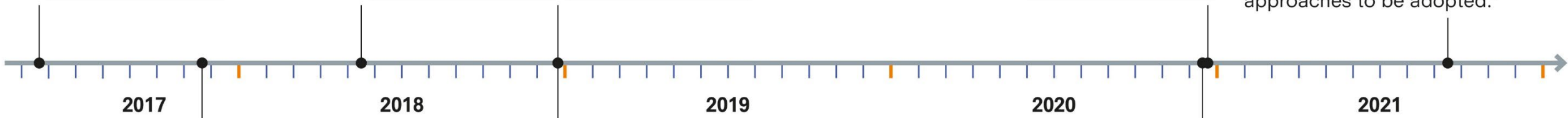
Platform Design Programme 'Defining the Need'



Transforming Infrastructure Performance: Roadmap to 2030



'A mandated approach: in the next two years the government will set out a requirement for platform approaches to be adopted.'



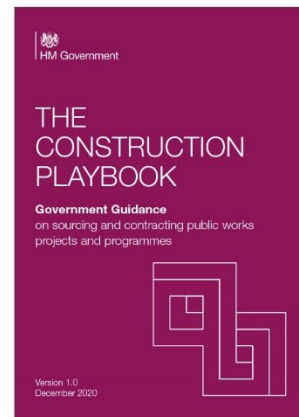
Click on icons for link



Autumn Statement
'The government will use its purchasing power to drive adoption of modern methods of construction...'



Construction Innovation Hub awarded £72 million to drive innovation + technological advances in the UK construction and infrastructure sectors.



The Construction Playbook

'We will procure projects based on product platforms comprising of standardised and interoperable components and assemblies, the requirements for which will be part of a digital component catalogue.'



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‘Platforms identify features of assets that could be shared and then harmonise those features’

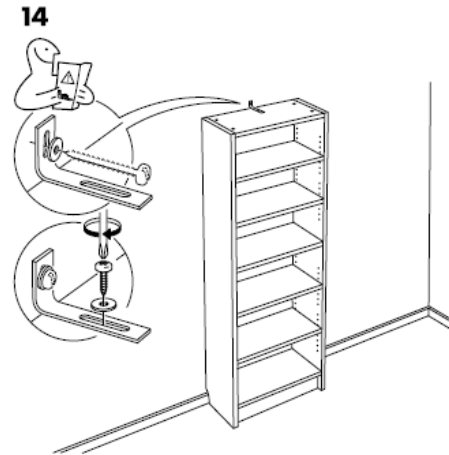
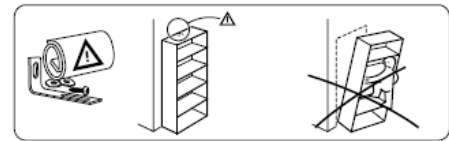
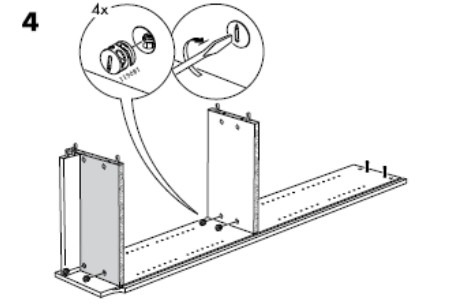
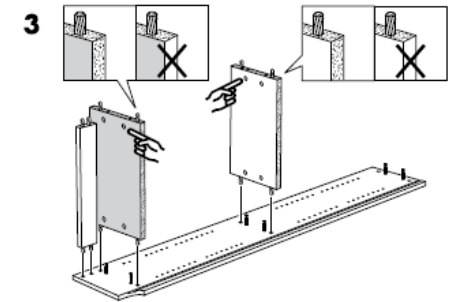
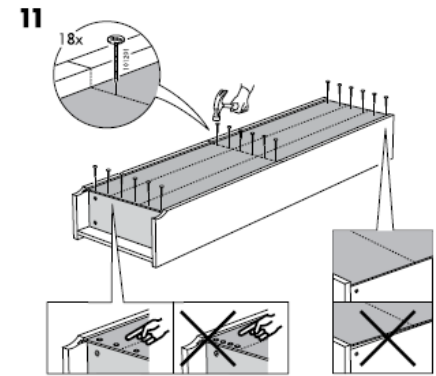
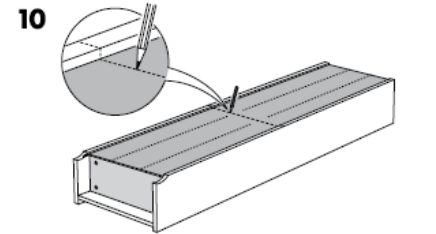
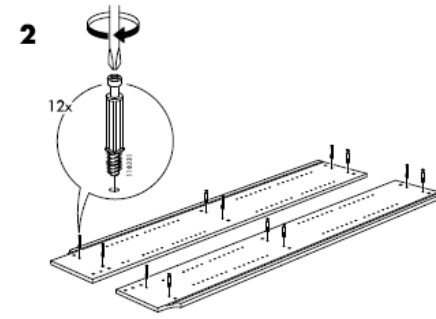
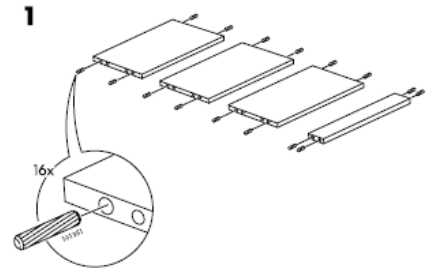
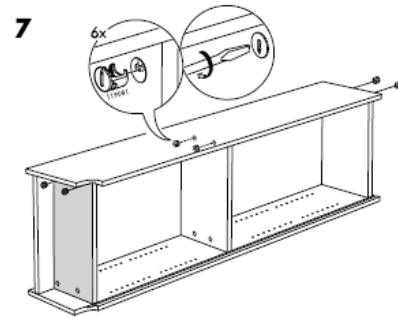
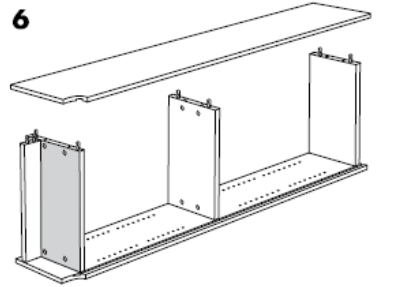
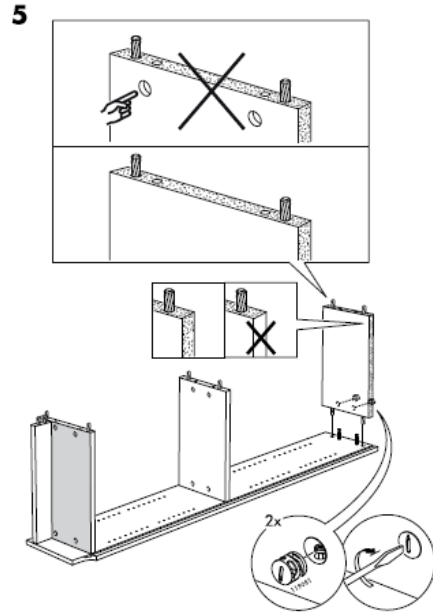
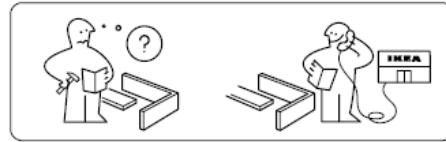
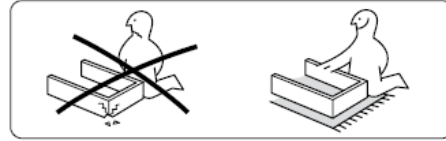
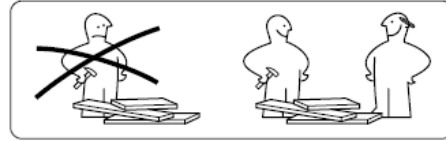
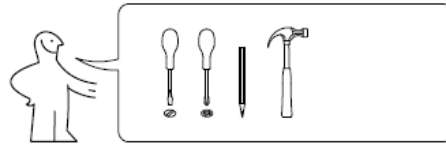
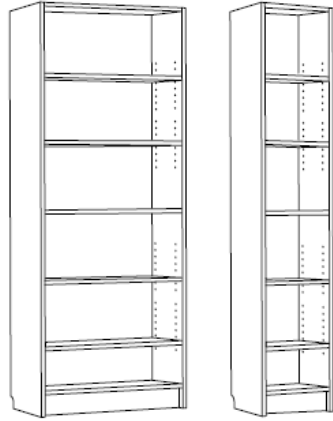
- This approach provides the opportunity to create common ‘kits of parts’.
- Harmonised cross-sector demand enables their manufacture in high volume, with configuration allowing delivery of multiple asset types across sectors (e.g., schools, apartments, healthcare facilities).

Transforming Infrastructure Performance: Roadmap to 2030, IPA, 2021



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BILLY





Infrastructure
and Projects
Authority

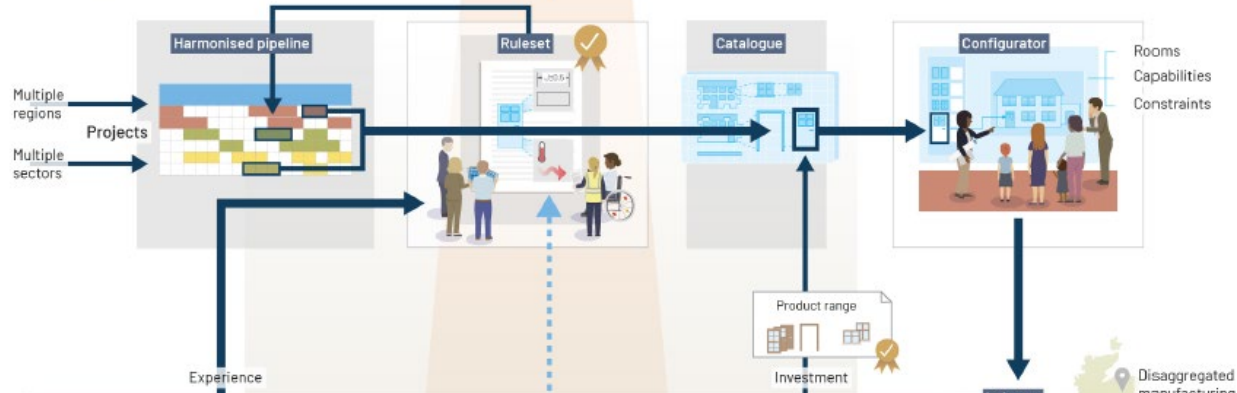
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Transforming Infrastructure Performance

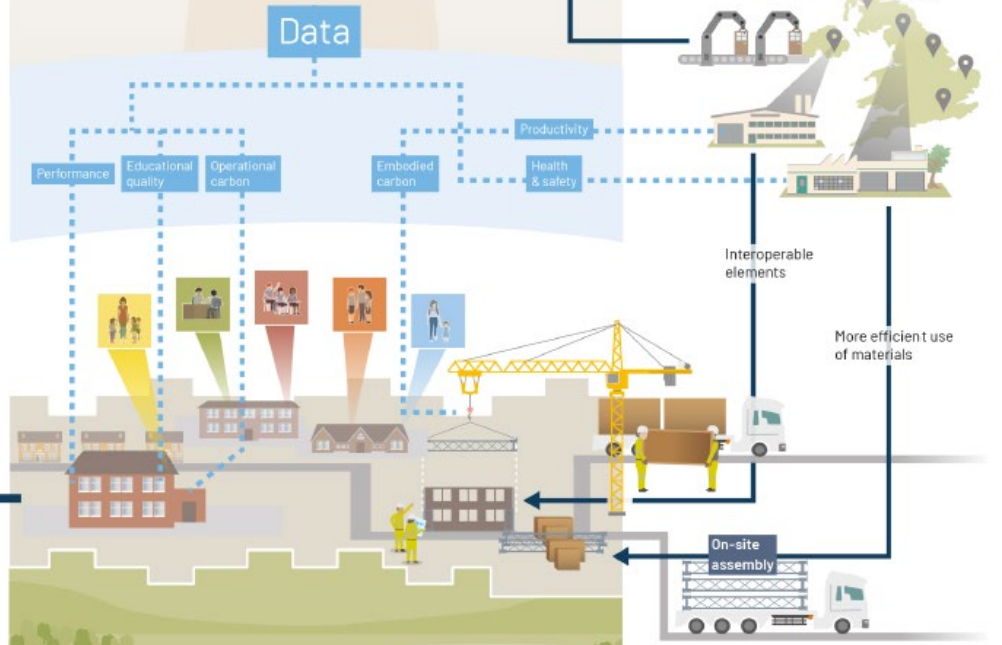
Addressing the need for social infrastructure using a platform approach



Policy



Systems of Systems



- Automation through the use of configurators enables a greater focus on value led elements of the design process, and assembly would employ digital workflows, machinery and robotics.
- Platforms enable productivity and efficiency akin to the manufacturing industry, creating productive capacity + the creation of inclusive stable manufacturing employment
- Factory conditions in construction - delivery via repeatable productive activities enables predictability and automation to improve health and safety, reduce waste, increase productivity and speed of assembly, and address the skills gap.
- Feedback loops - platforms can enable data to inform the whole ecosystem, from rules to product catalogue. Digital models and twins would enable assurance and feedback throughout delivery and use.

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1016726/IPA_TIP_Roadmap_to_2030_v6_1_.pdf



<https://vimeo.com/394805860>



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Digital configurators

- Some of the greatest design stage benefits of platforms will be realised through the use of applications referred to here as 'configurators'.
- These configurators marry the rules with **component data in the digital catalogue to automate the generation of design**, from a schedule of rooms to a digital asset model and could ultimately provide outputs such as a full cost breakdown or a list of approved suppliers.
- Configurators can result in **much faster design** and the consideration of a **greater range of permutations**.
- They can enable the **involvement of local communities and professionals** at earlier stages, and they can support the quality assurance process that enables the tracing and recording of critical data from design through to operation.



Configurators



REM

Roads
Highways England



Living Lab

The Tube
TfL



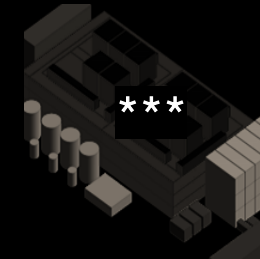
PRiSM

Homes
Mayor of London

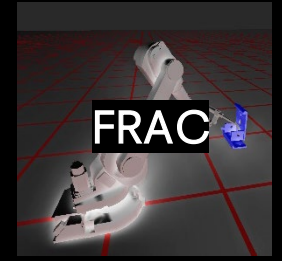


P2P

Homes
Prism to Platforms



Data centres



FRAC

Robotics
Open source



RAID

Rail
Network Rail



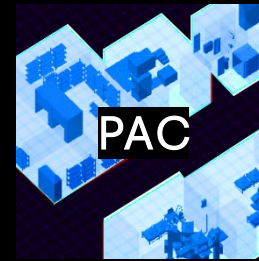
SPACED

Cycling
DfT



SEISMIC

Schools
DfE



PAC

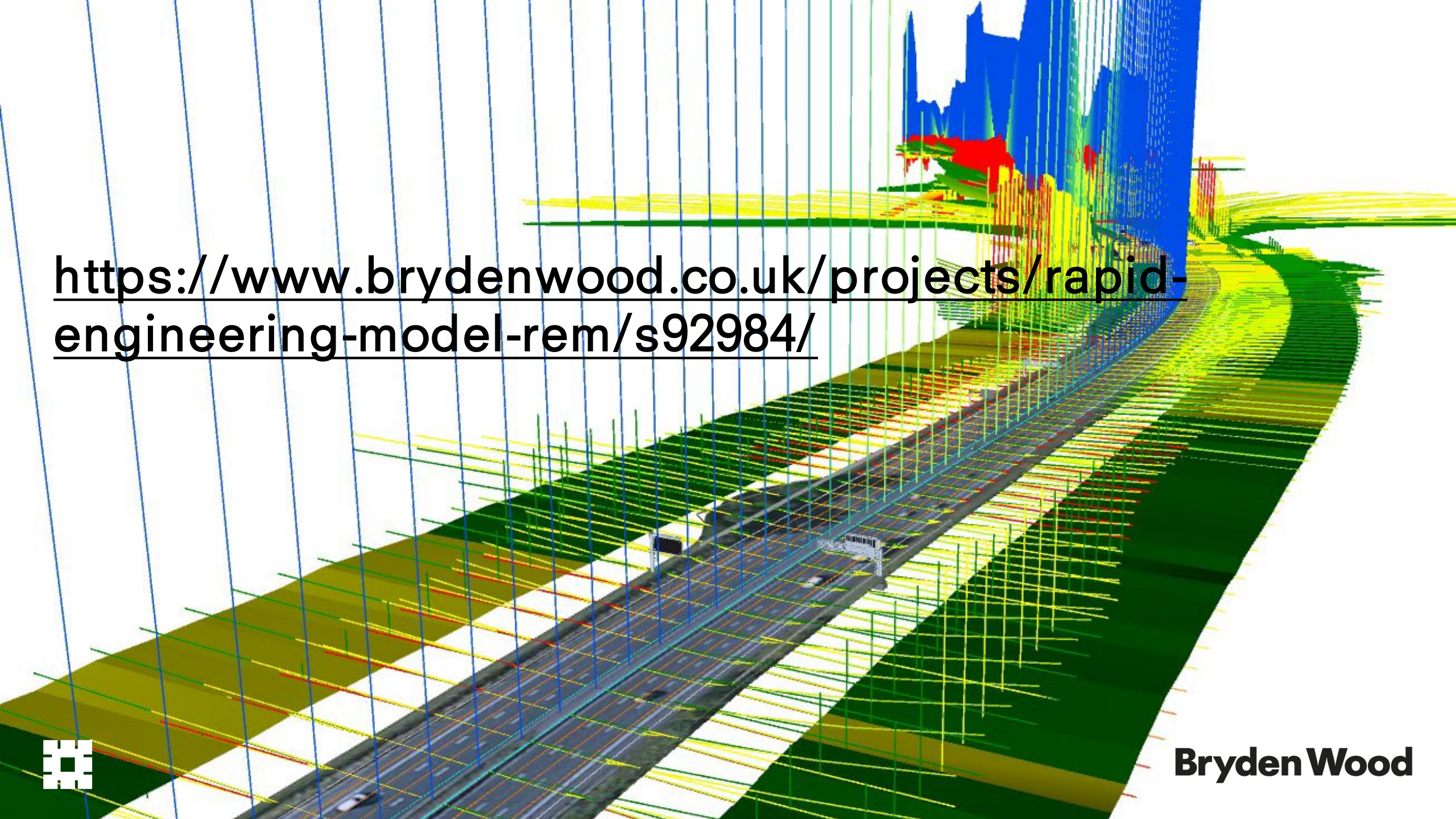
Pharmaceutical
GSK



FASTtruss

Industrial
Innovate UK





<https://www.brydenwood.co.uk/projects/rapid-engineering-model-rem/s92984/>



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A Platform for Repurposing Coal

- Repurpose 2TWe coal fleet
- De-risk clean energy transition
- Social, economic and environmental justice benefits

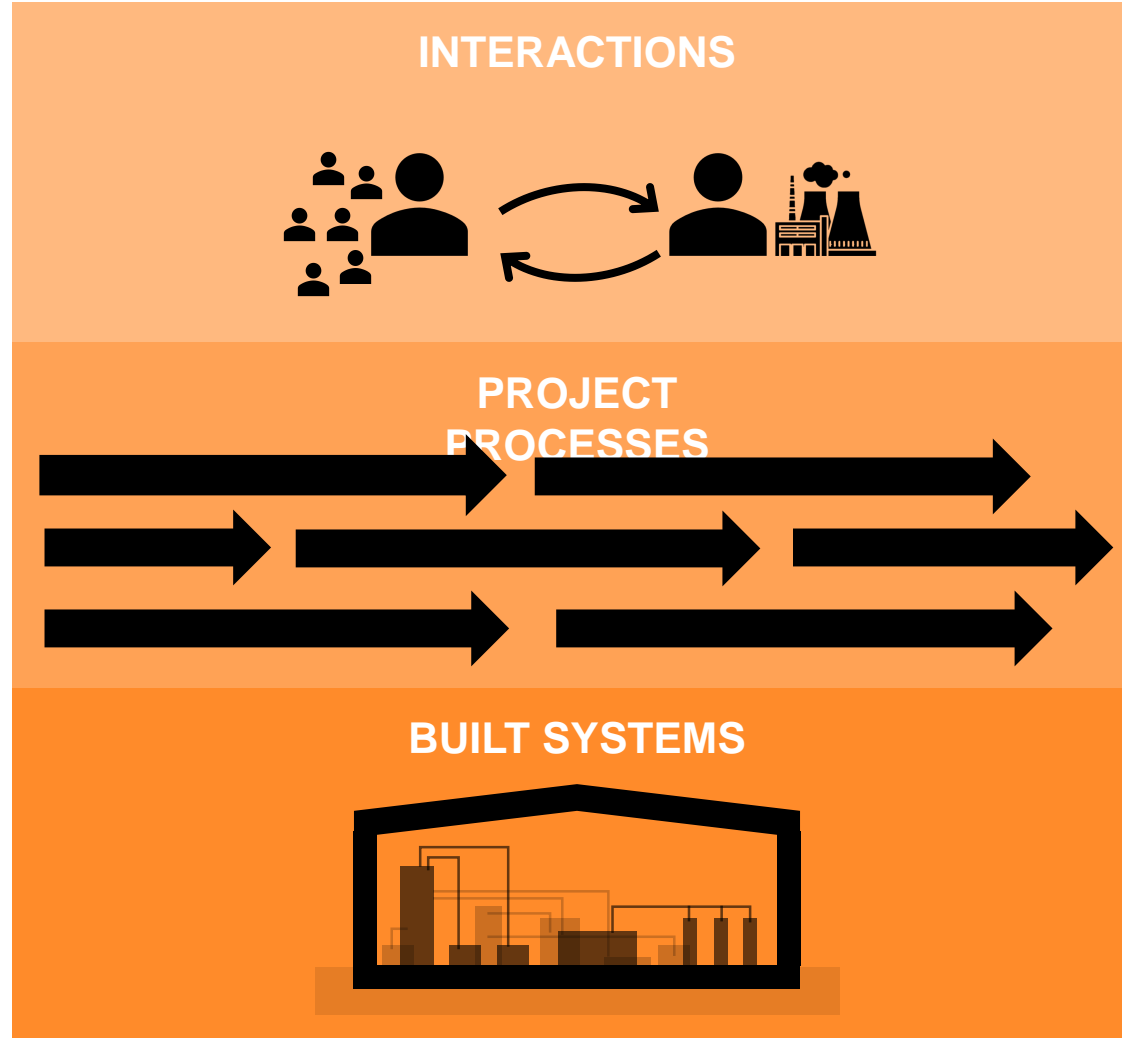


Current deployment model is too slow and cannot scale

The Need



2,000
400
GW
sites/year



The Problems

Costly, slow,
risky

Few customers
want it

Few suppliers
can provide it

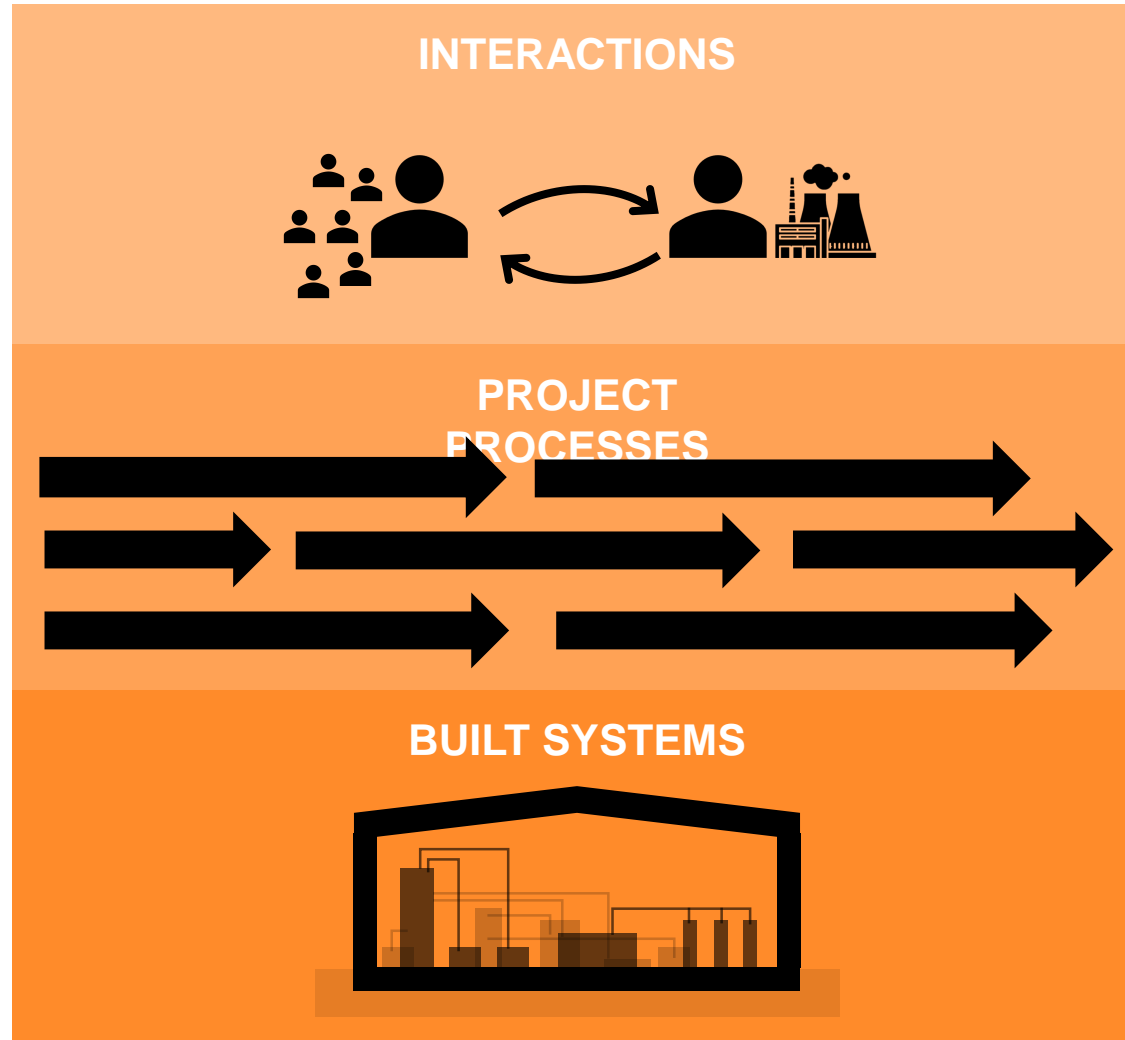


What if we took a design approach to systematically address all these challenges?

The Need



2,000
400
GW
sites/year



The Problems

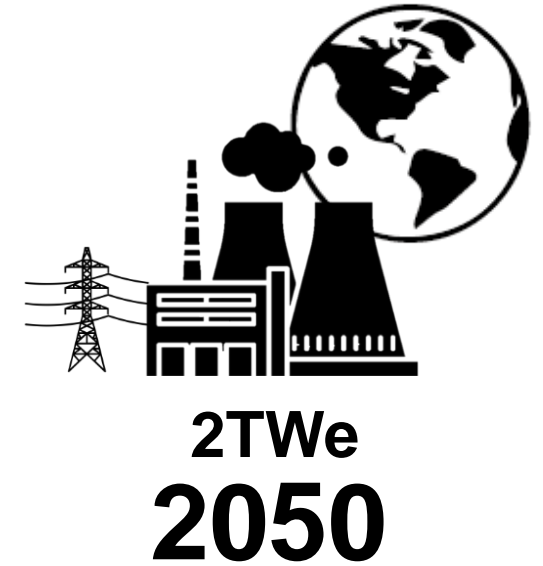
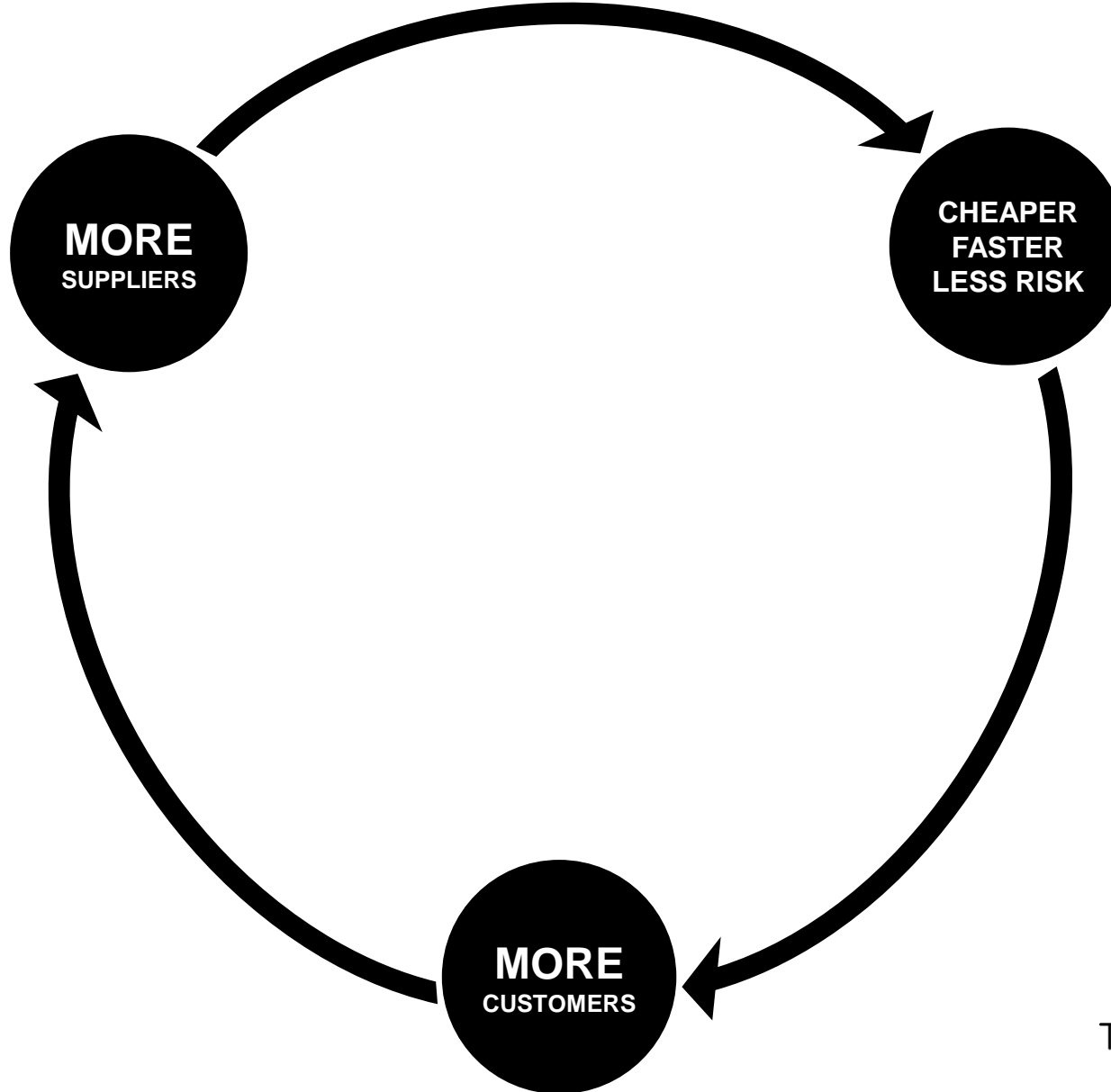
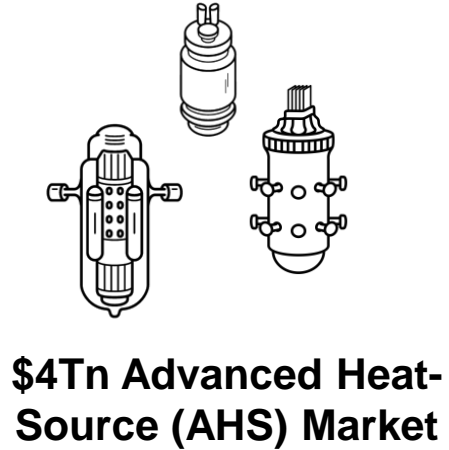
Costly, slow,
risky

Few customers
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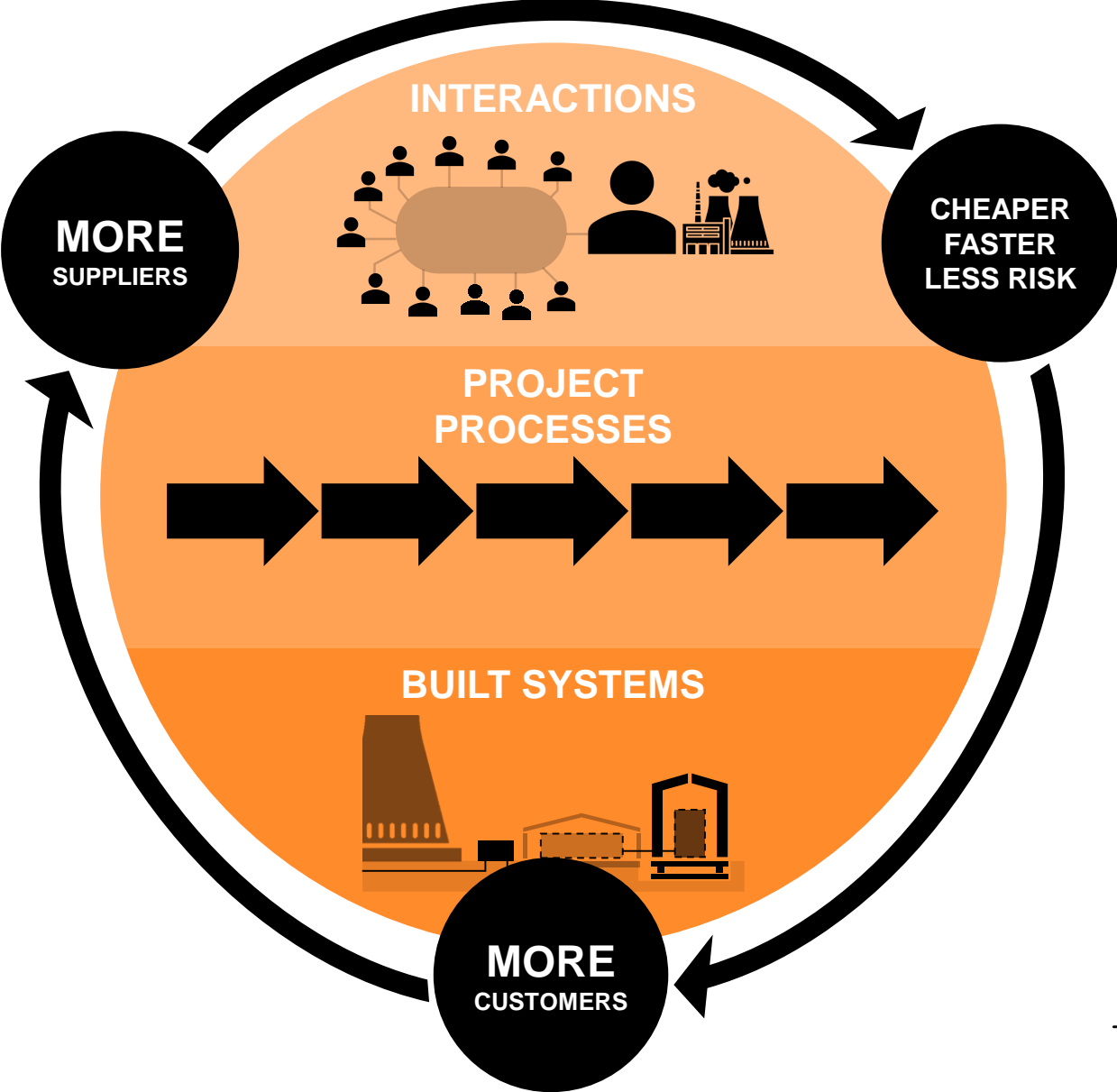
Few suppliers
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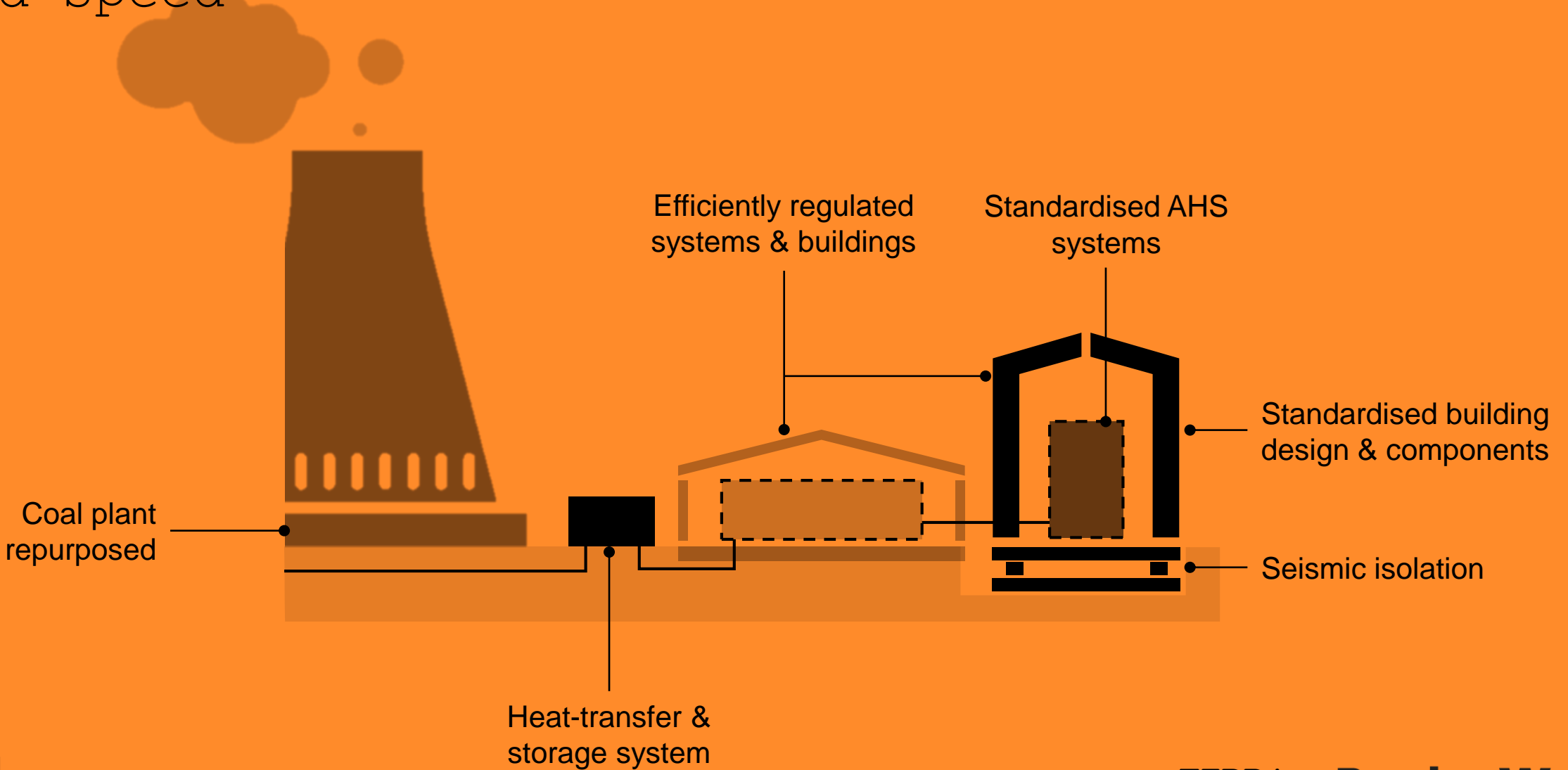
What would this new system need to do?



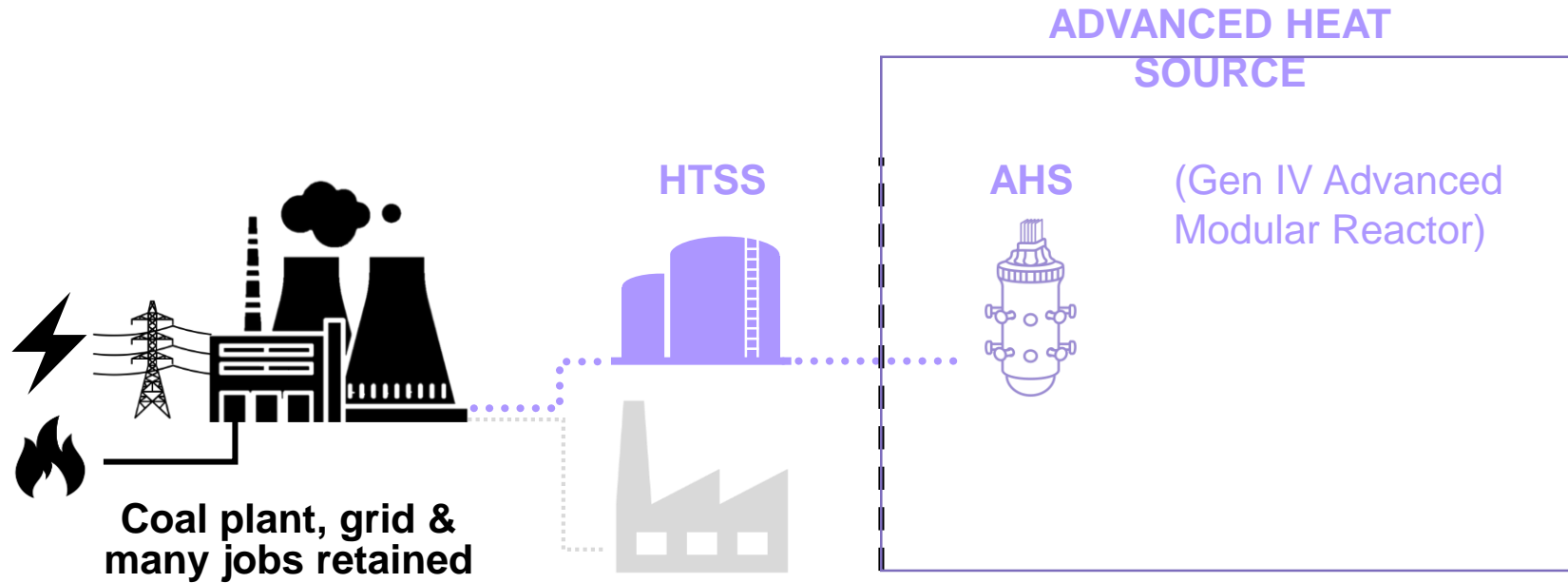
Coordinated Platform Approach



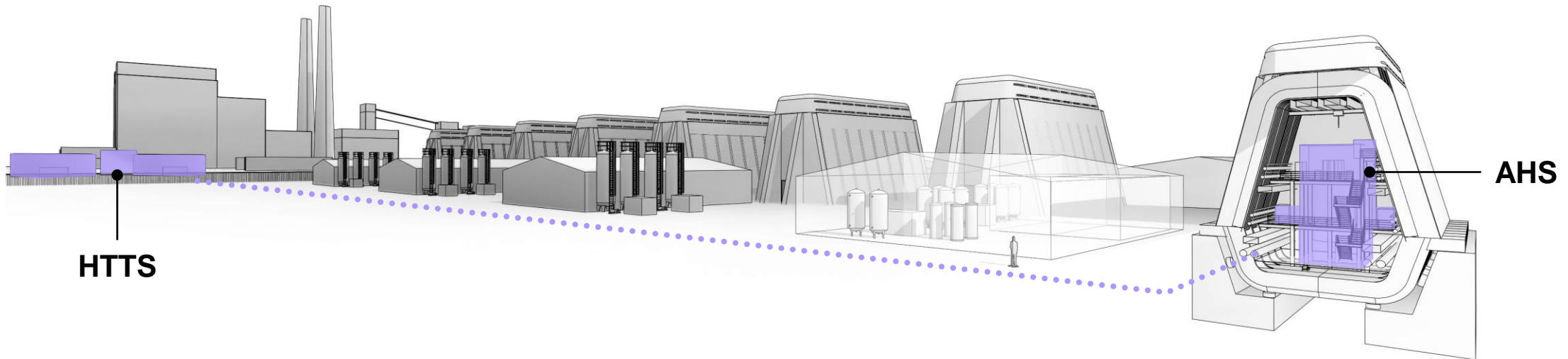
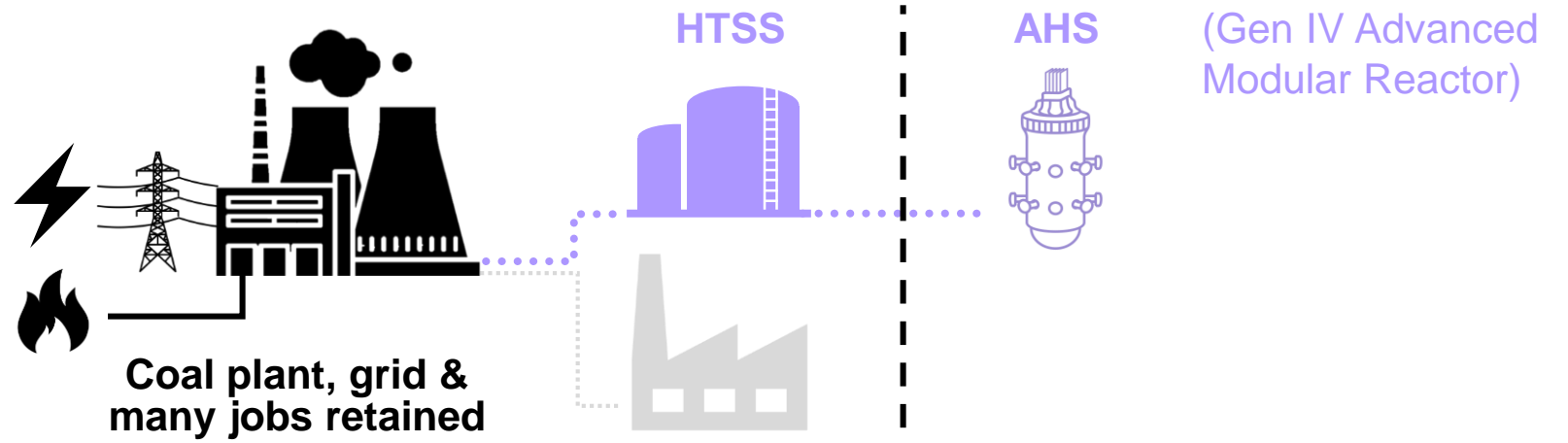
Built Systems Must Enable Scale and Speed



Reduce the scope of nuclear systems

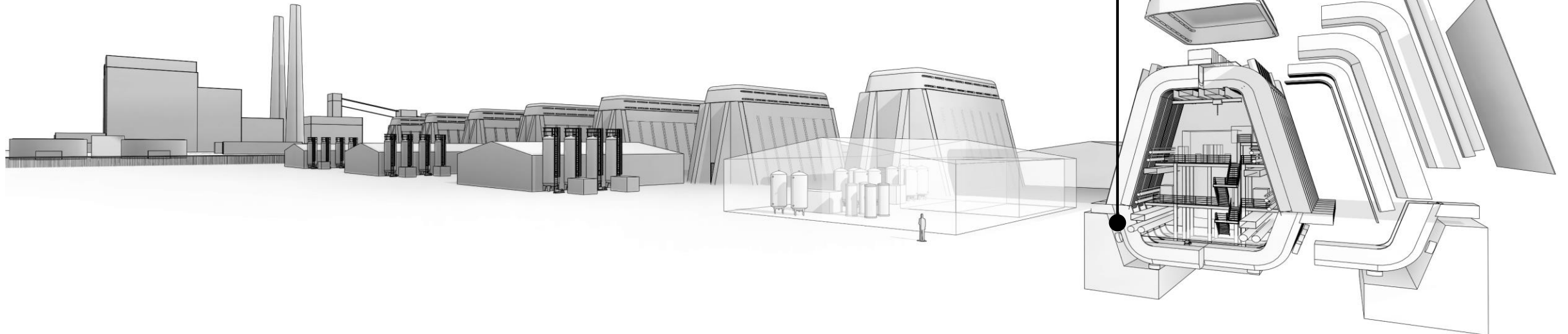
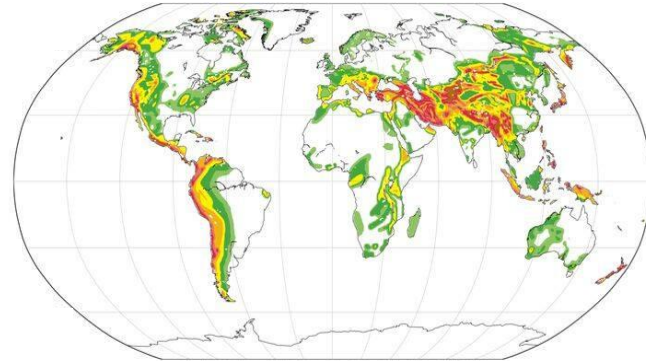


Reduce the scope of nuclear systems



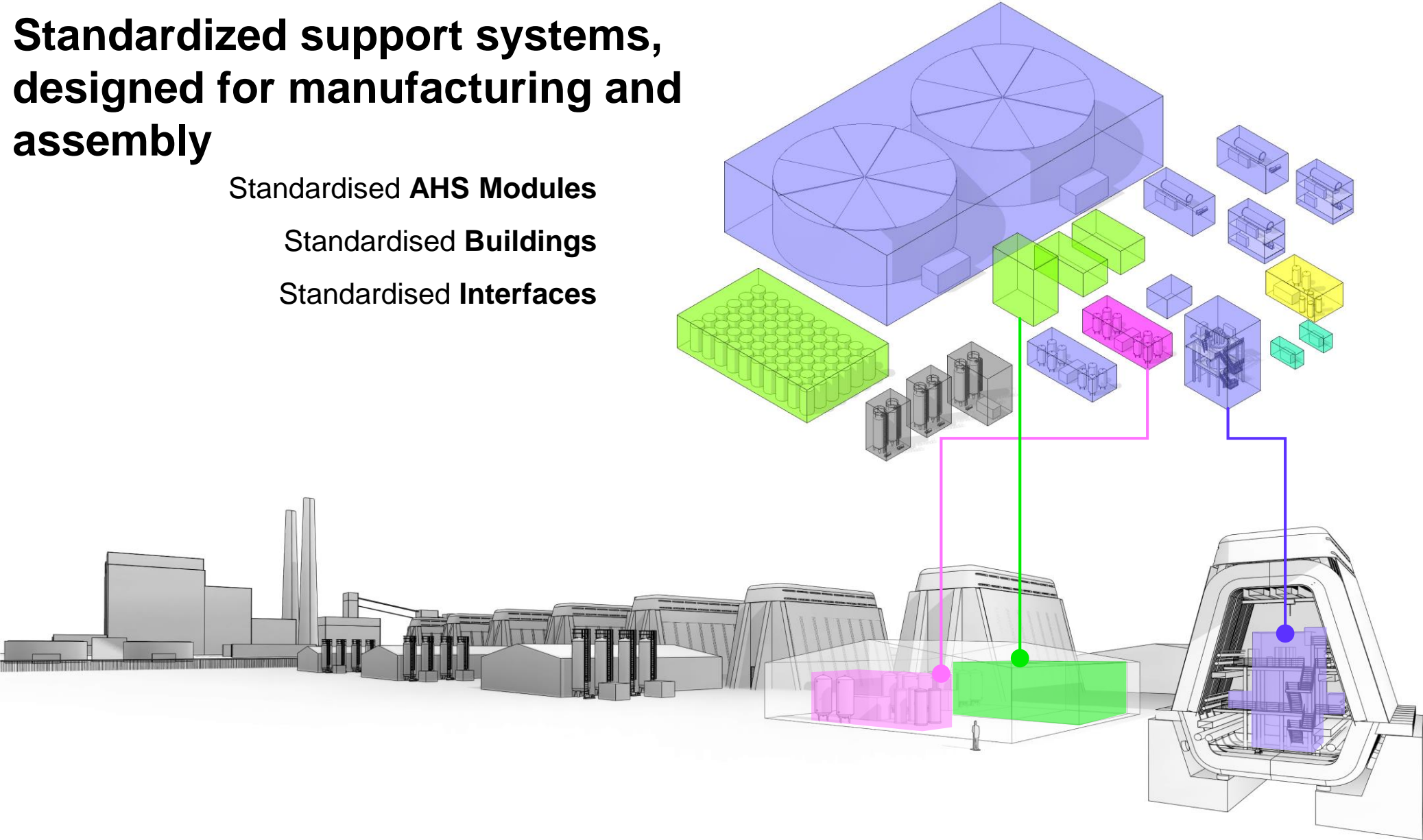
Seismic isolation to enable standardized design

Range of seismic isolation systems means site can be treated as standardised

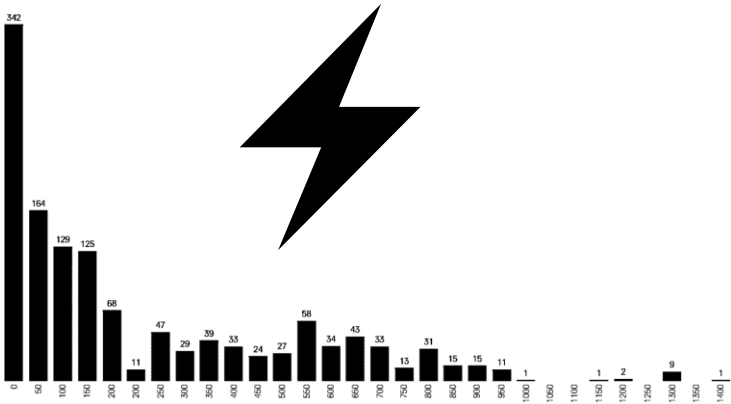


Standardized support systems, designed for manufacturing and assembly

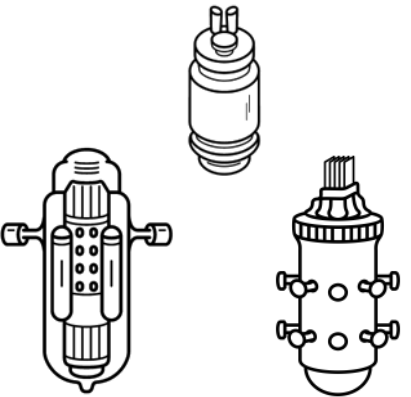
- Standardised **AHS** Modules
- Standardised **Buildings**
- Standardised **Interfaces**



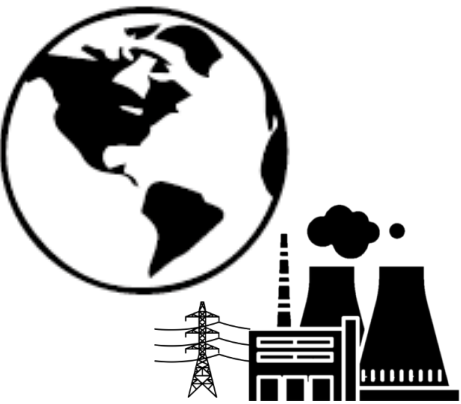
The physical build system enables standardisation while addressing a wide variety of requirements



Different
Energy and heat requirements



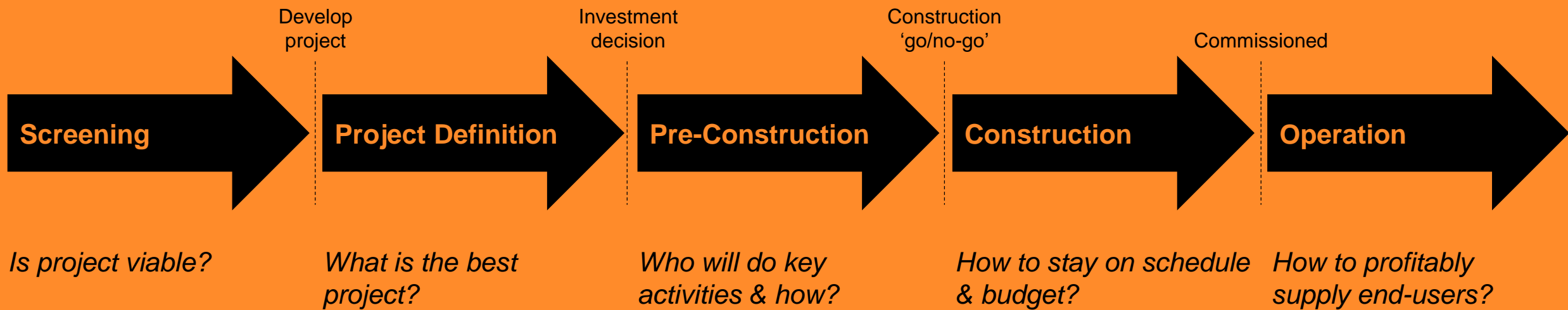
Different
Advanced heat-source (AHS) technologies



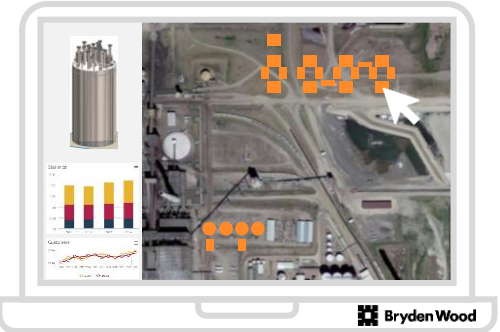
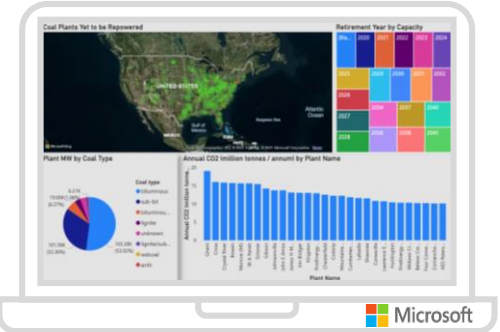
Different
Site layouts and local requirements



Project Processes Must Enable Scale and Speed



Customers Assess Viability with Cloud-Based Tool

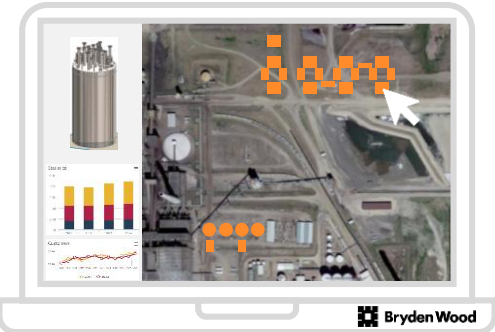
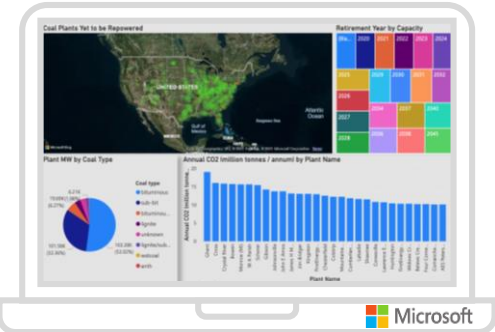


Automated Design – Components Designed for Manufacture

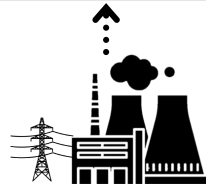
Screening

Project Definition

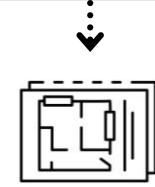
Pre-Construction



Reference design



Project-specific design



Standard info for suppliers



Standard info for regulators



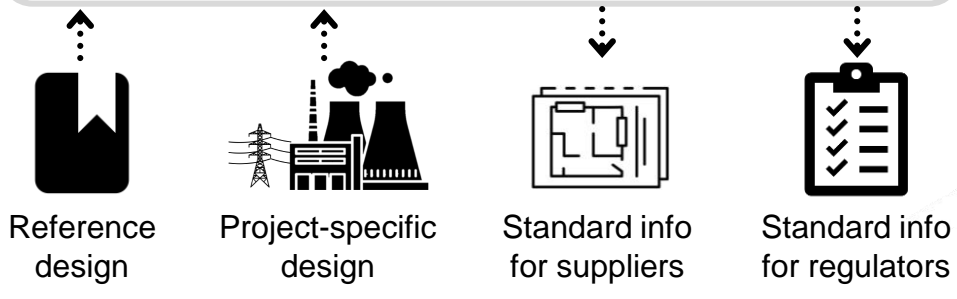
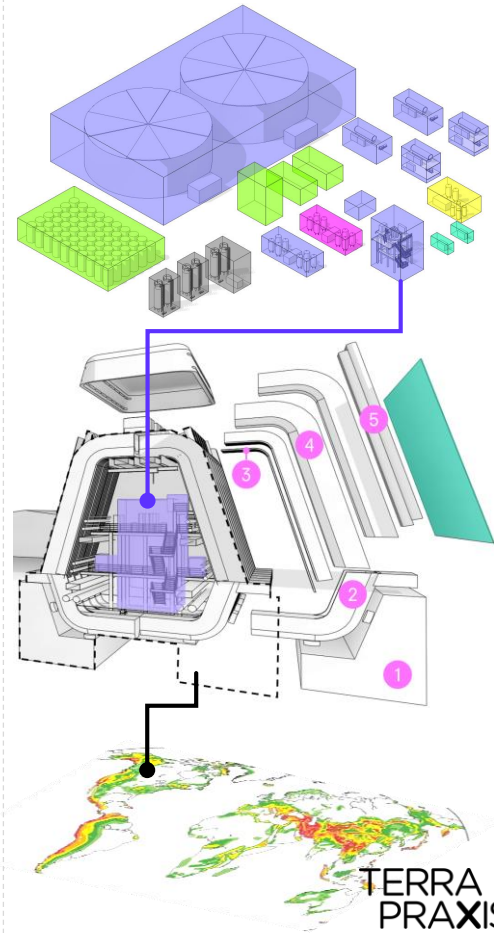
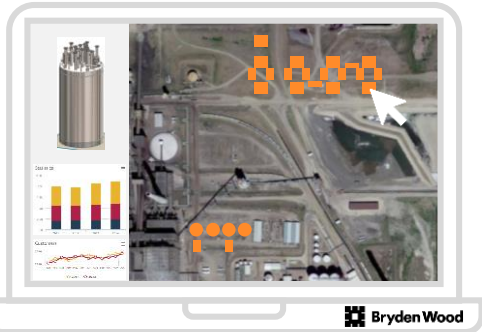
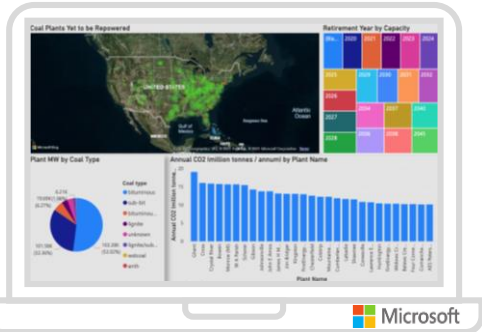
Manufactured Components Assembled On-Site

Screening

Project Definition

Pre-Construction

Construction



TERRA PRAXIS

Bryden Wood

Heat can be Delivered as a Service

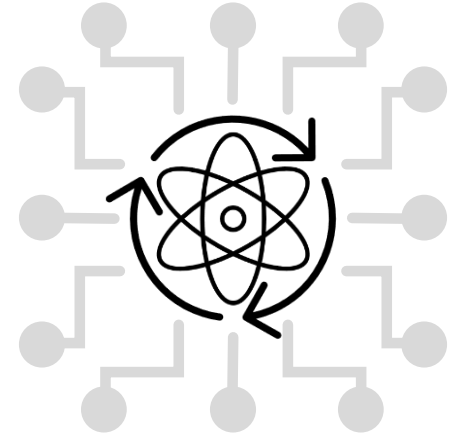
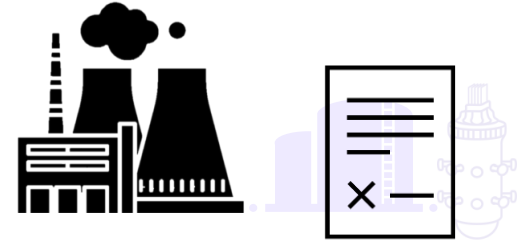
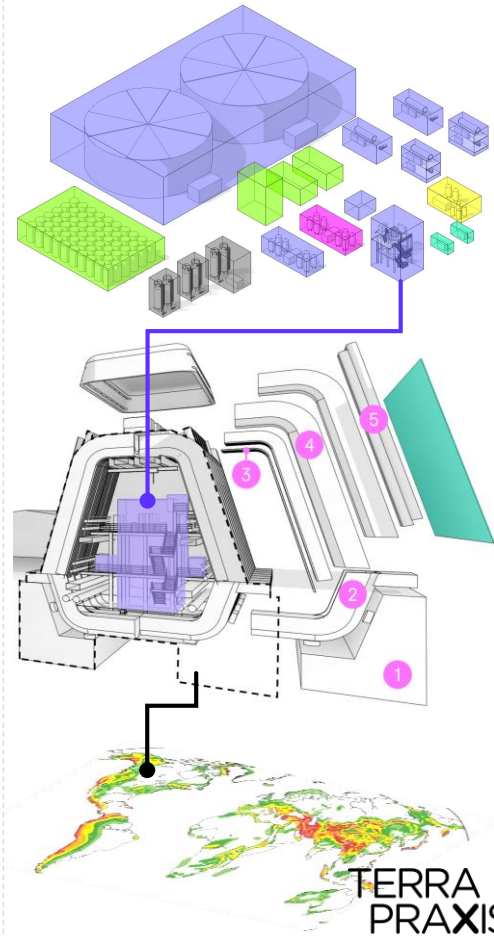
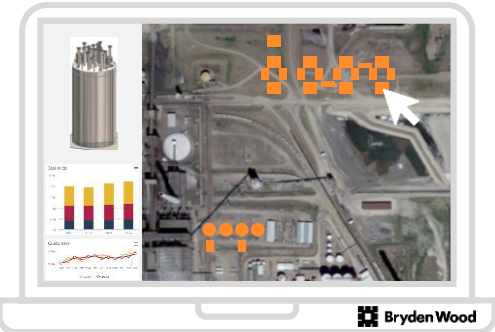
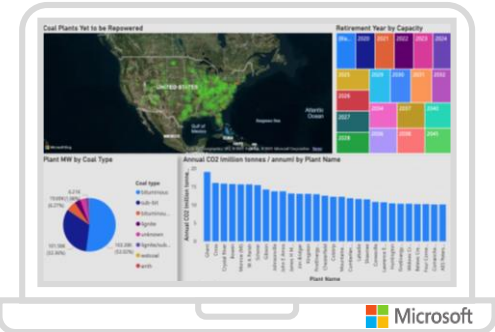
Screening

Project Definition

Pre-Construction

Construction

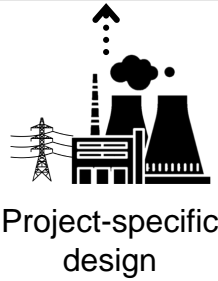
Operation



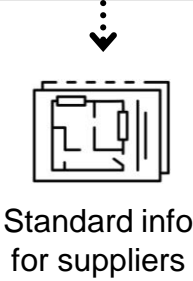
Wide nuclear materials / waste supply-chain



Reference design



Project-specific design



Standard info for suppliers



Standard info for regulators



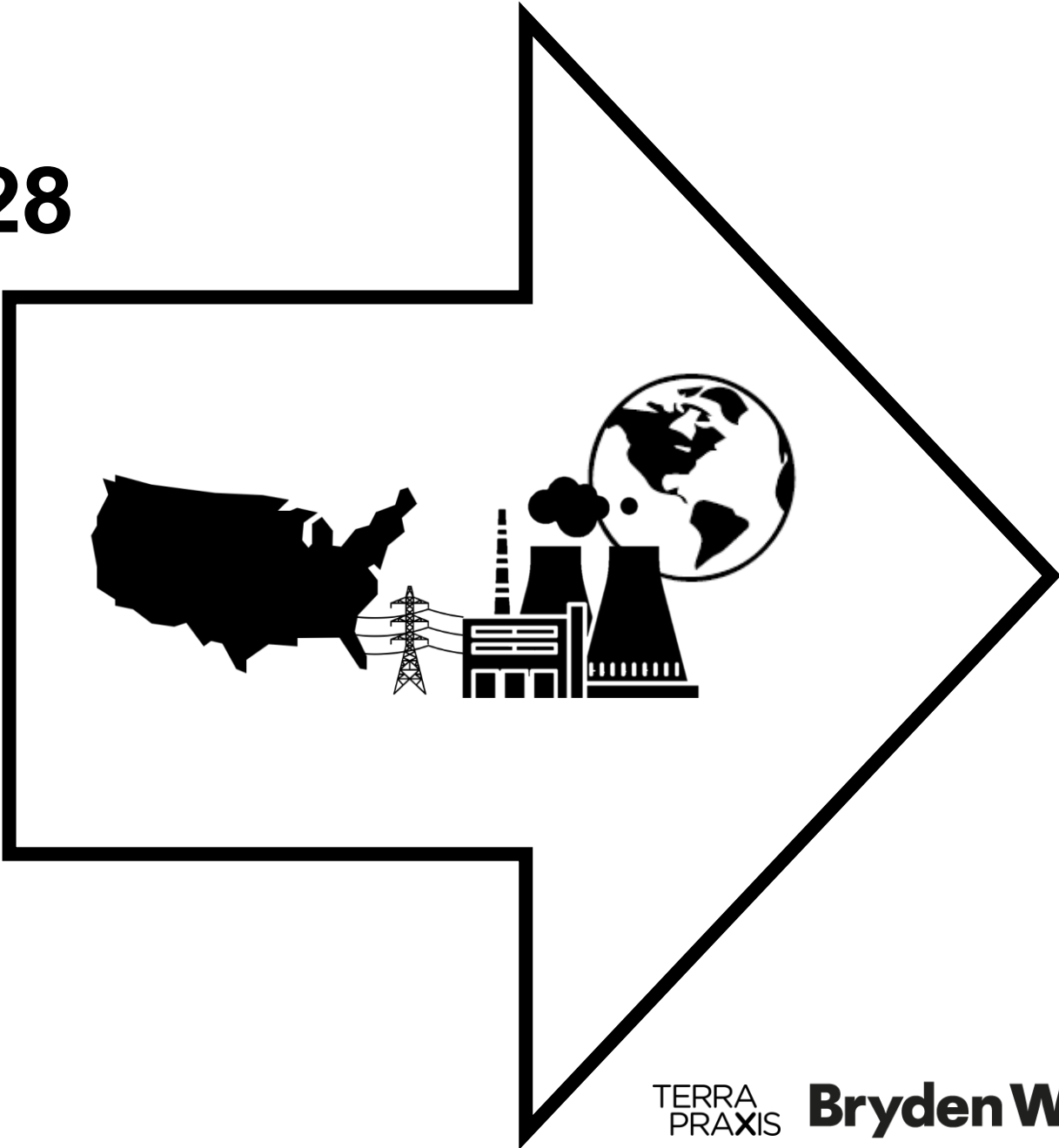
Bryden Wood

Mass Deployment

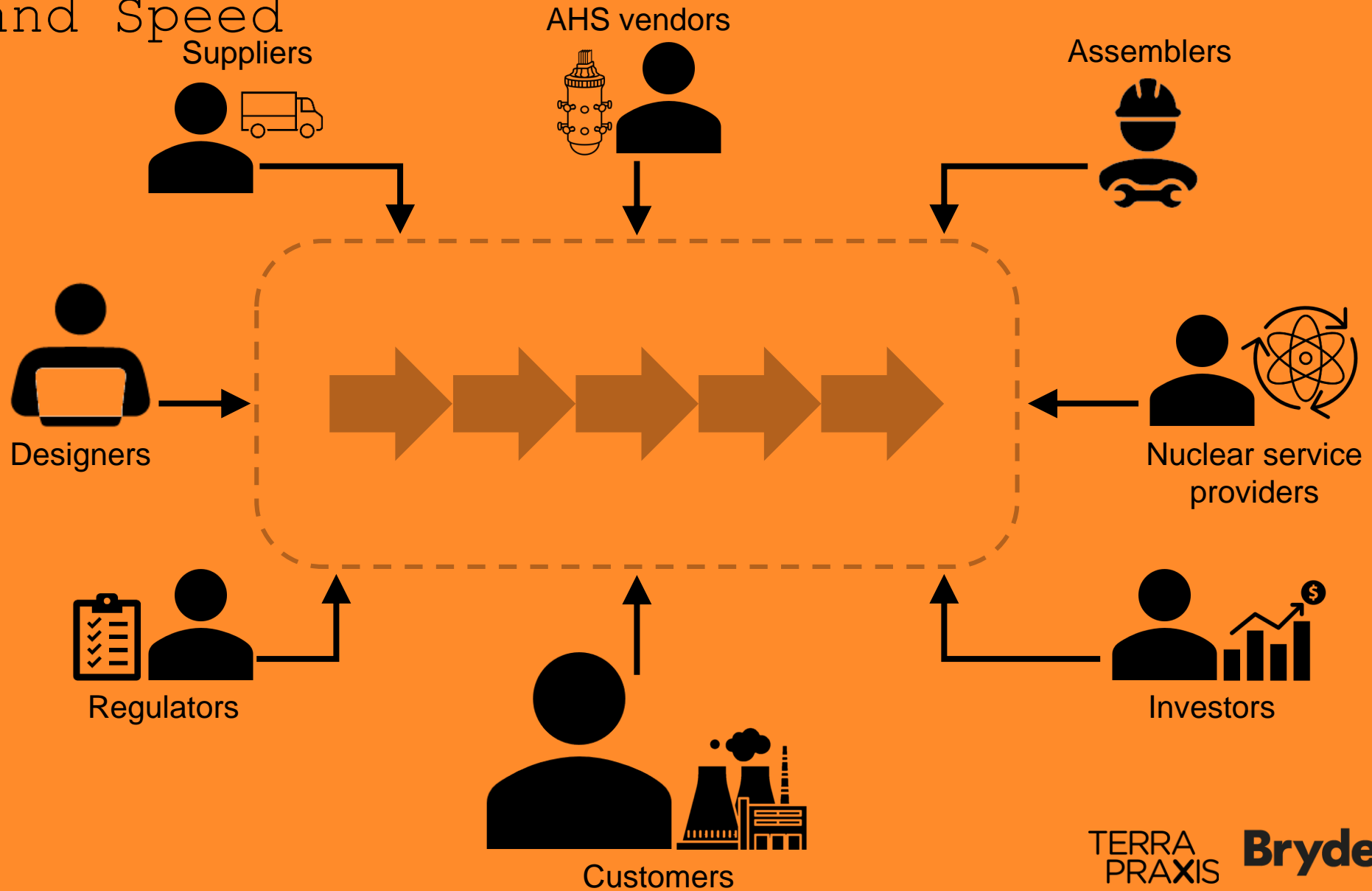
2028

PROJECT DEVELOPMENT

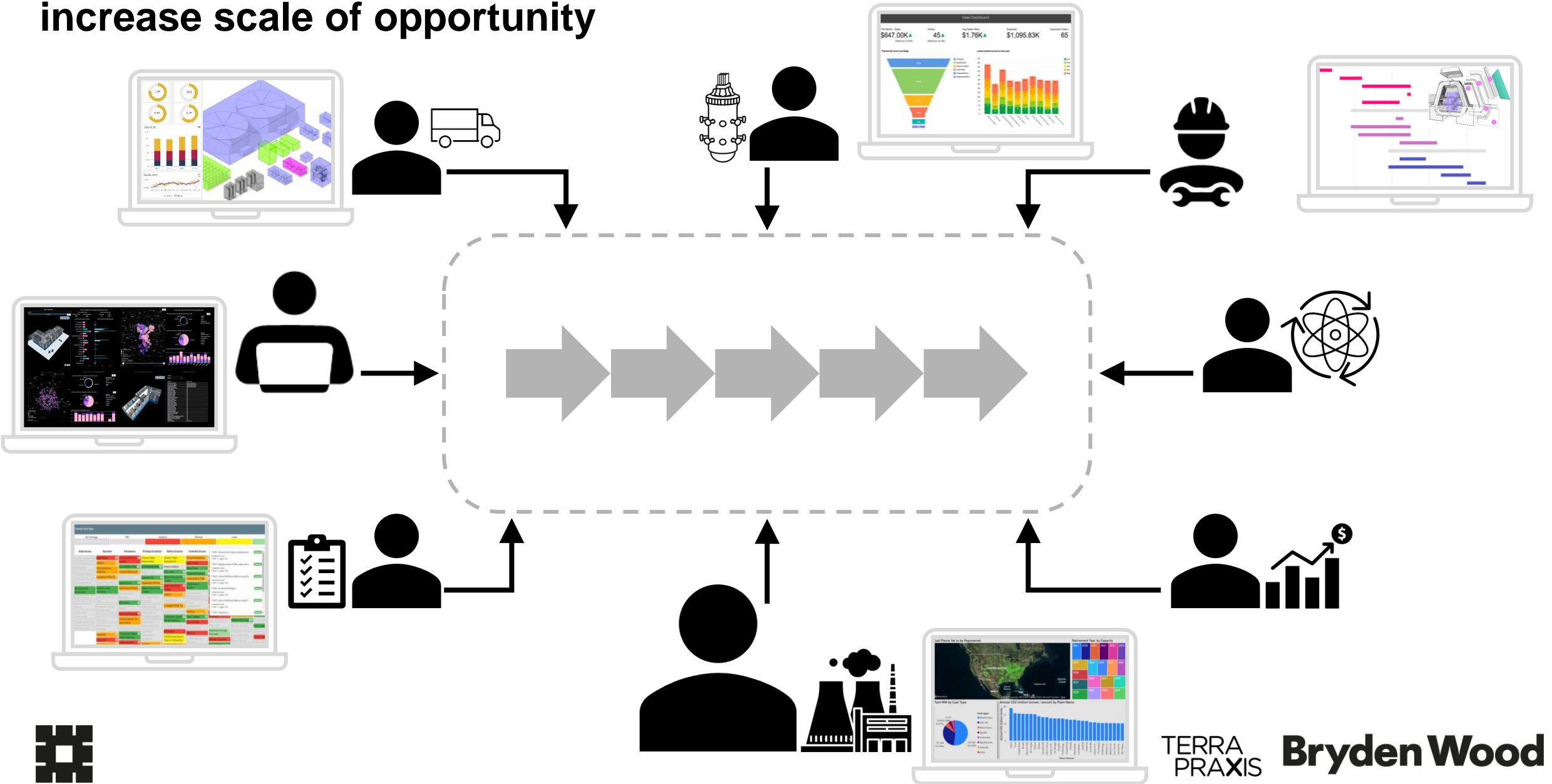
ADVANCED HEAT SOURCE
DEVELOPMENT



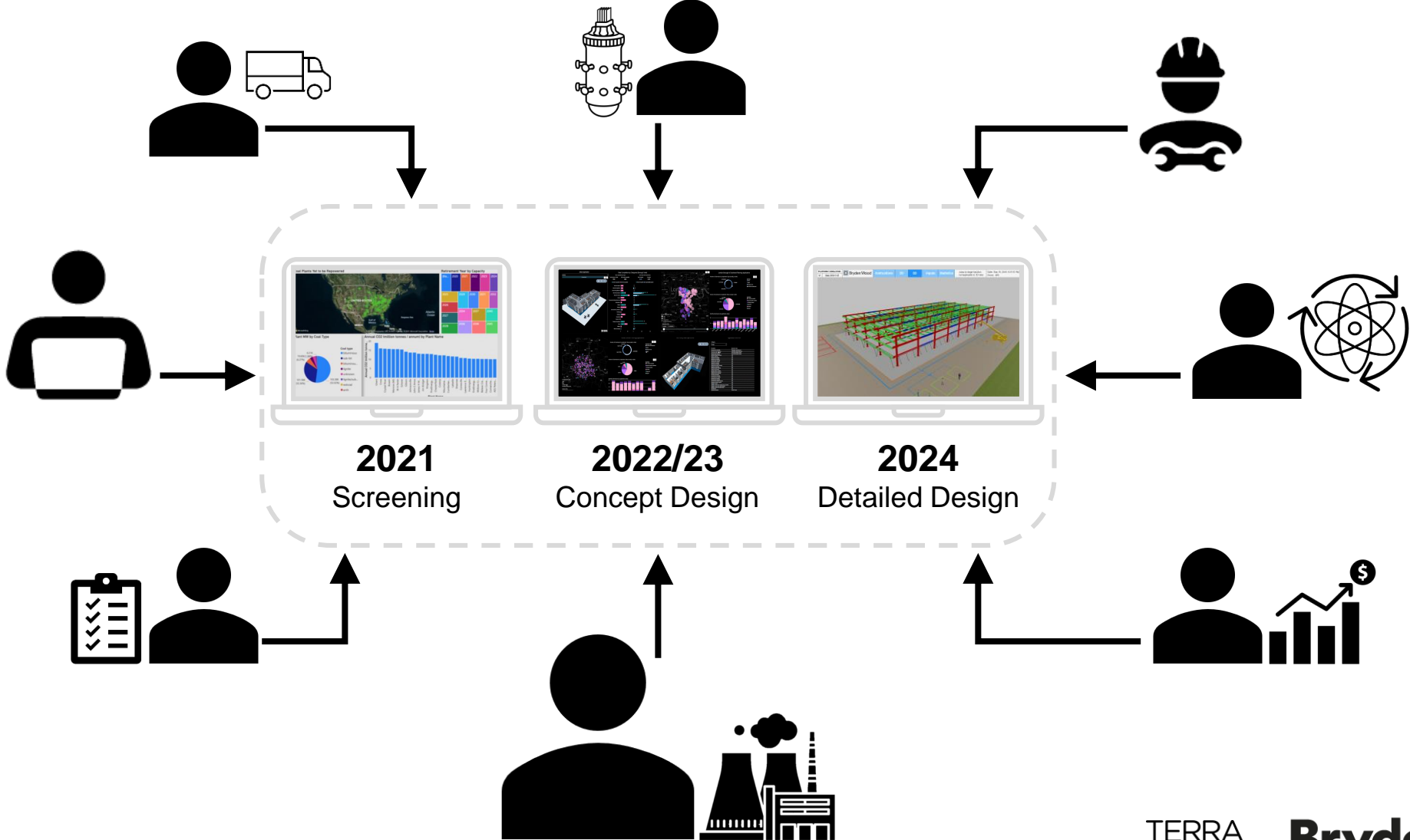
Interactions Must Be Redesigned to Enable Scale and Speed



Reduce interaction cost and increase scale of opportunity



Enable supplier/stakeholder access to expanding project pipeline

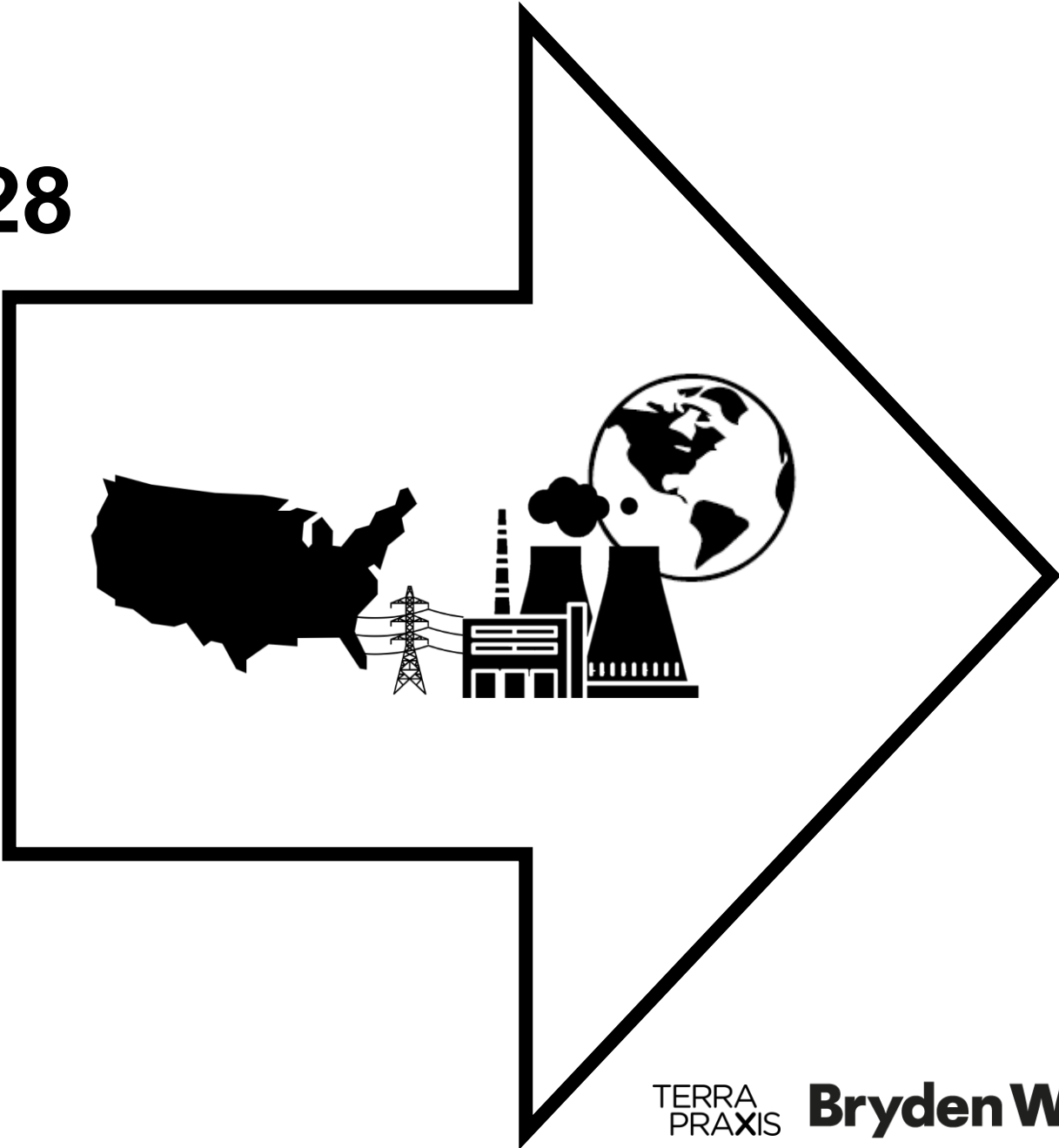


Mass Deployment

2028

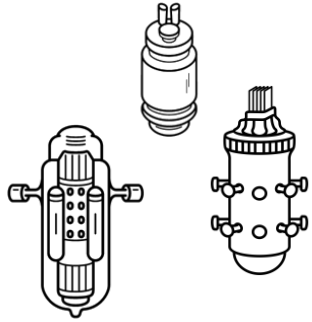
100'S OF PROJECTS

MULTIPLE HEAT SOURCES PRODUCTS

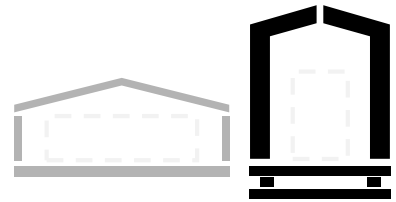


This Platform Can Repurpose 2TWe of Coal

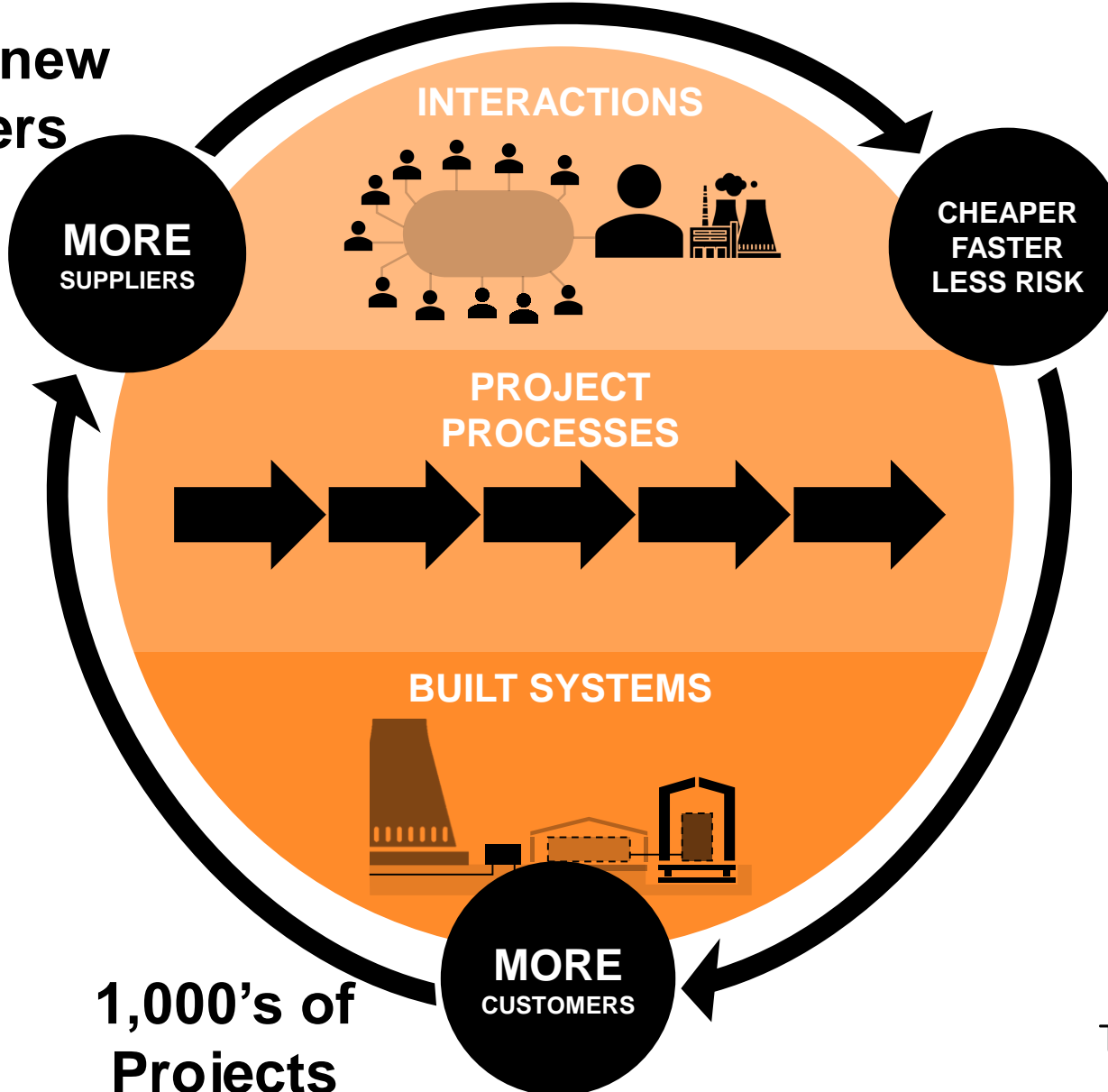
100's of new suppliers



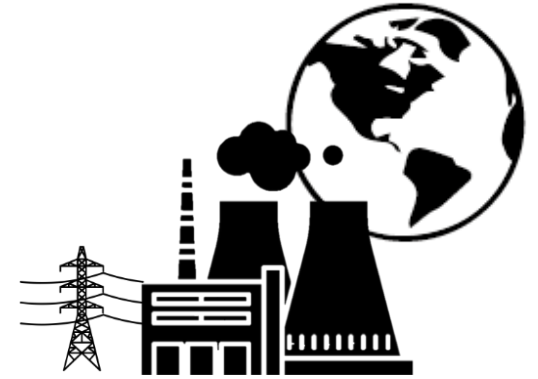
\$4Tn Advanced Heat-Source (AHS) Market



Global Market of Productised Building Systems



Less than \$2,000/ kW



2TWe
2050

1,000's of Projects