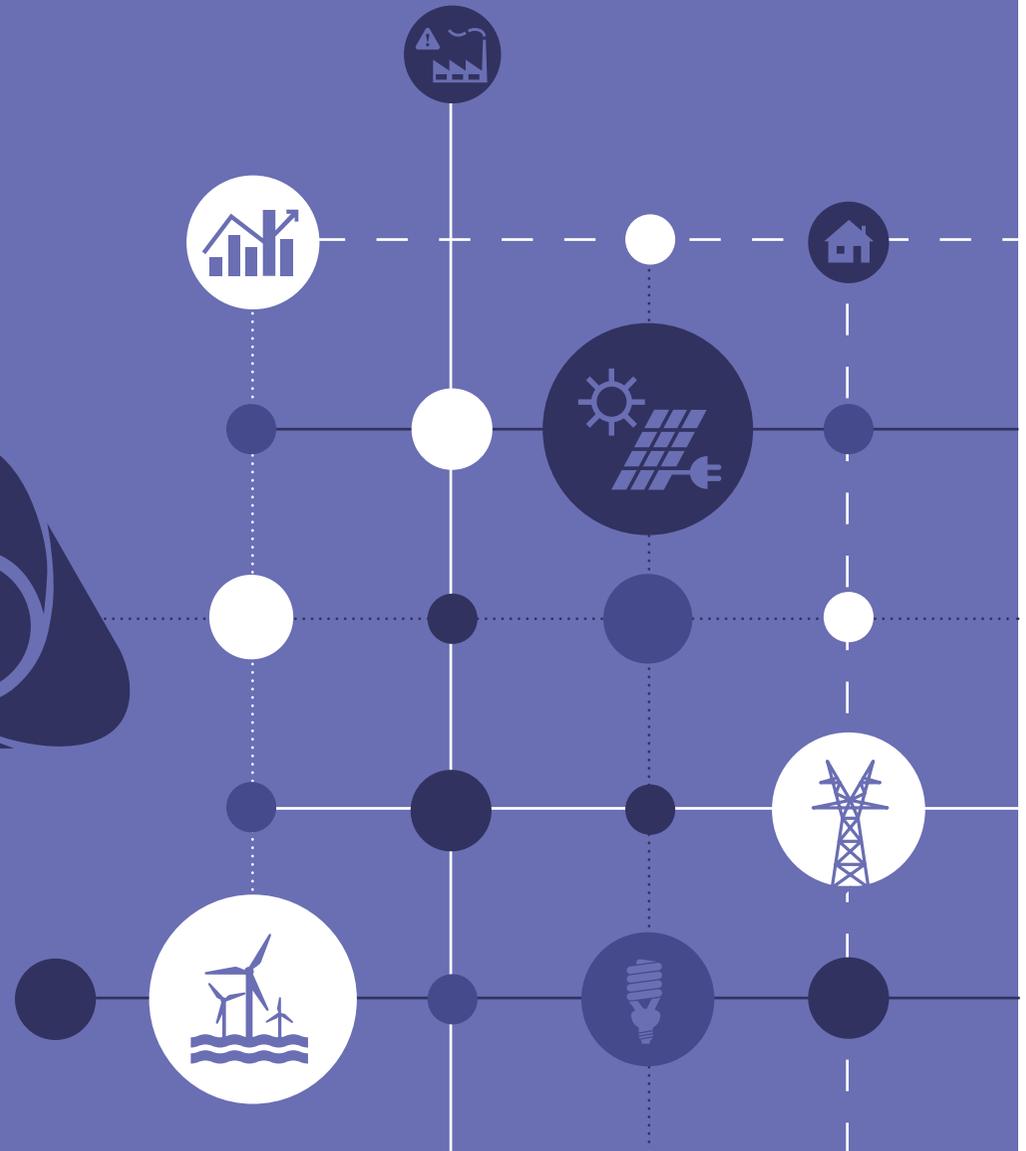


Five minute guide

Energy Trilemma



Energy Trilemma

As world population continues exponentially growing and becomes more urbanised and more affluent, demand for power, heat and transport will grow with it. Global energy demand is expected to increase just as fast and potentially double by 2050.

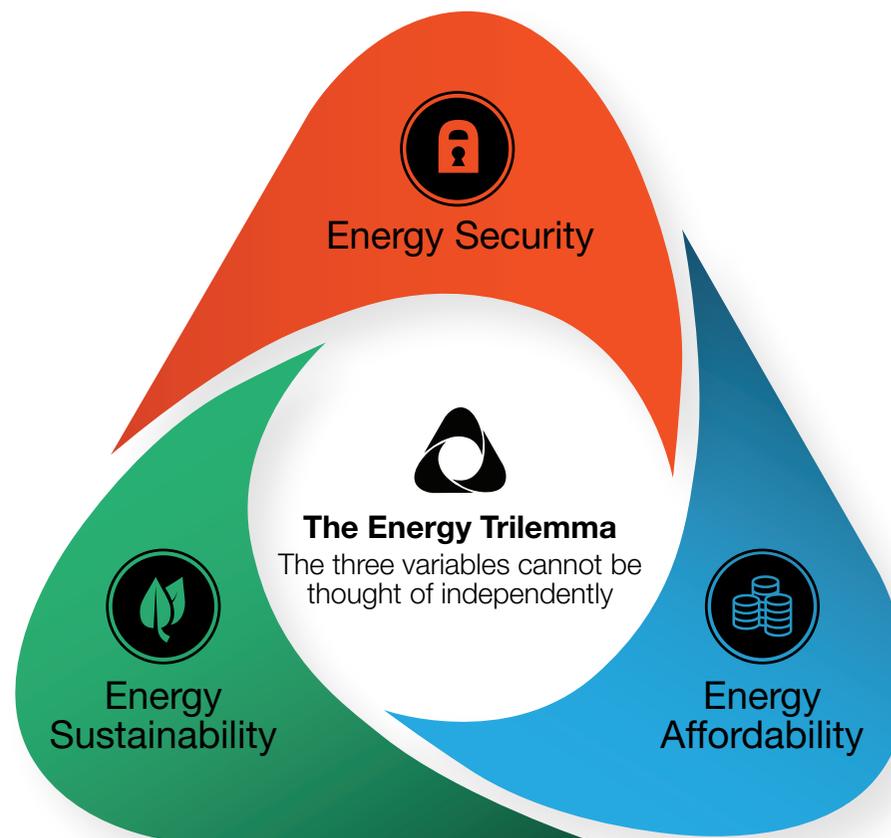
To keep up with global energy demand, the investment requirements for energy infrastructure are nearly US\$50 trillion between now and 2050.

With such a large portion of money being invested, and the need for energy becoming ever so critical, the method of resource allocation is paramount.

There are three challenges that have to be addressed when facing investment in energy and demand, and these three challenges imply a trade-off when choosing one over the other. These three challenges constitute the Energy Trilemma:

- Energy Security
- Energy Sustainability
- Energy Affordability

Much of this guide is written referring to the Energy Trilemma in the context of countries and national performance. It can equally be applied to cities or large organisations and individual projects. It could even help large multinationals determine the appropriate geographic emphasis for their activities.



Why is the Energy Trilemma an important tool?

The trilemma can be thought of as three independent axes, each with their own scoring or weighting.

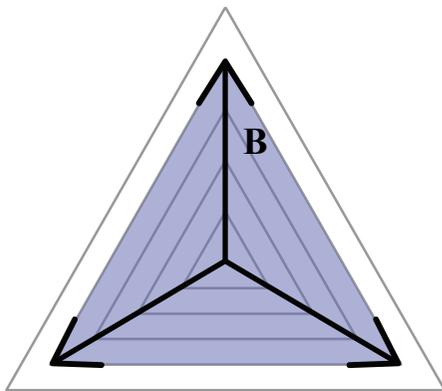
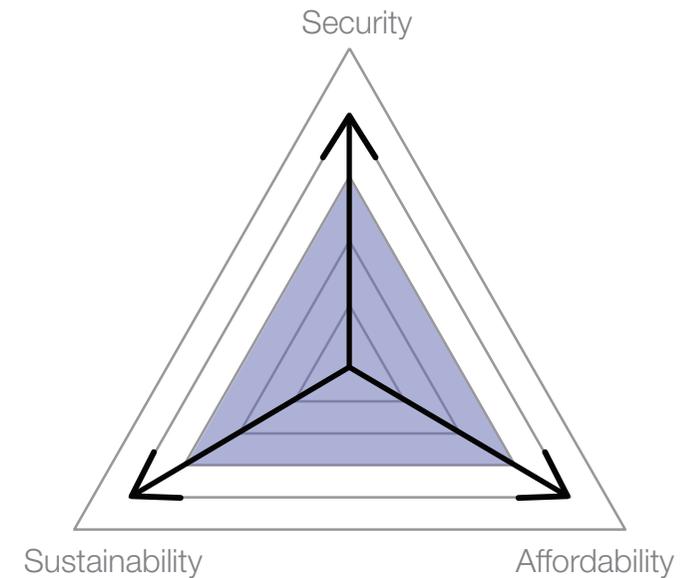
A good score will be on that is higher on a particular axis. No one axis is necessarily more important than the other two, so the optimum is to achieve high scores on all three.

The challenge then becomes the achievability of this. The value of the Energy Trilemma as a tool is it powerfully communicates the relative positioning against all three.

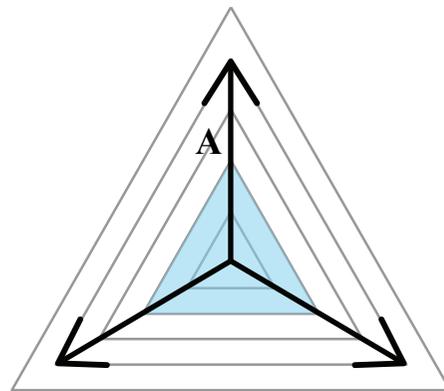
So why is it useful?

Countries, cities and large organisations can set policy or socio-corporate strategy by identifying where they want to be on each axis and what is the desirable resilient position. They can benchmark their current positioning. This enables a reality check and proper understanding of the existing influences and drivers. to achieve an informed position and be able to compare performance relatively to the performance of other equivalent entities. A constructive dialogue is possible on a reasonably consistent basis, without getting lost in an impossible maze of data.

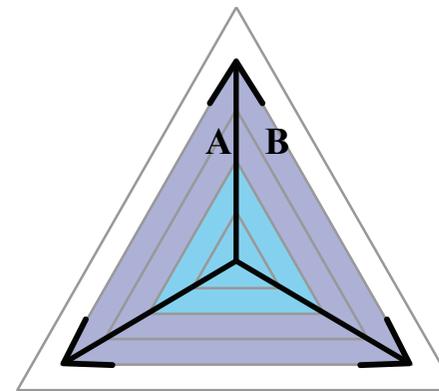
The power and value of the trilemma tool is then its ability to test whether new policies or projects are helping or hindering moving towards the desired position and what adjustments or change in emphasis of such new initiatives are needed.



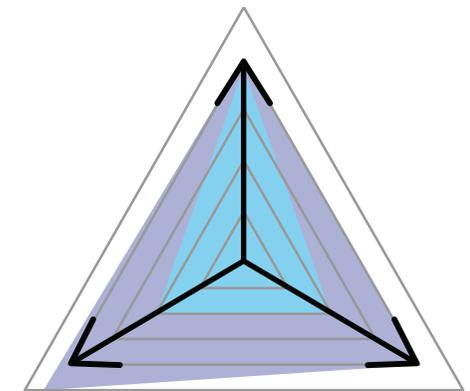
Step 1: Set the desired position



Step 2: Know where the current position is



Step 3: Test new milestones, policies, projects to see if they move from a to b



Step 4: Identify further initiatives that will compensate for the insufficiencies of those in step 3.

Energy Trilemma – Security

Energy security is the effective management of primary energy supply from domestic and external sources, the reliability of energy infrastructure, and the ability of energy providers to meet current and future demand.

Long term energy security requires suitable investments to supply uninterrupted energy. An example of a country with strong energy security is Australia, as it has abundant natural resources and good ports infrastructure. On the other side of the spectrum is a country like Luxembourg, which is landlocked and has no resources of it's own.

Historically, security has related to oil and gas resources and security can be threatened due to the political influence and volatility in oil markets. However, energy security must also encompass a country's reserve margins and its ability to keep the lights on. For example, although Australia has high natural reserves, due to limited power and refining capacity it has a poor reserve margin score.

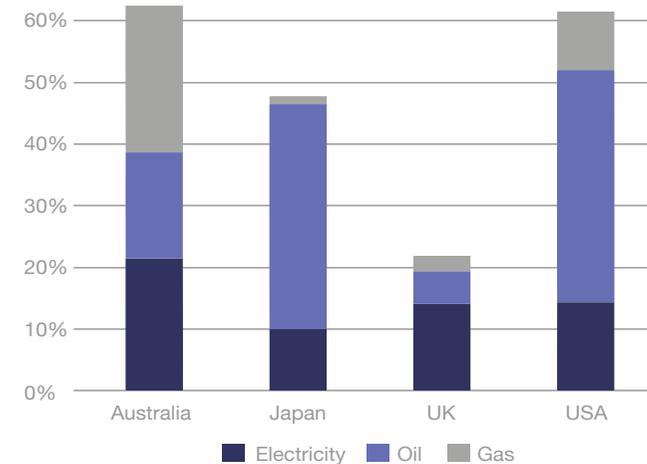
Reserve Margins

Reserve Margins are the margin between the maximum demand that can be reached in a country or energy system and the available capacity it has. Below is a selection of countries and how they rank in each energy source.

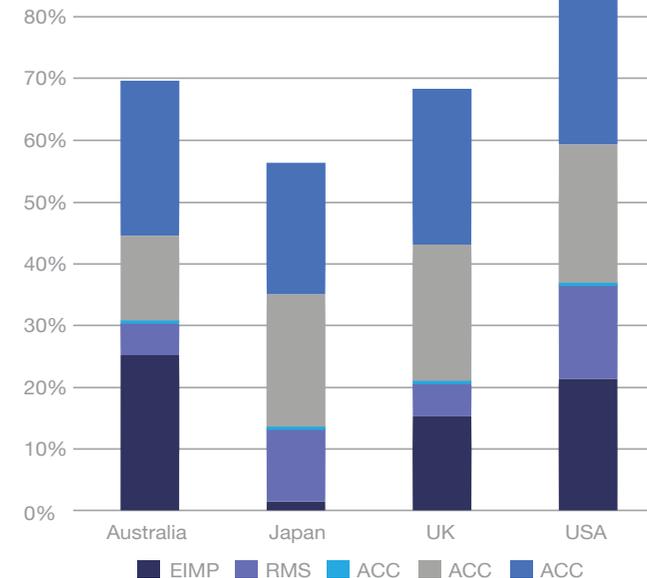
Energy Security Index

The Energy Security Index is built between 4 key security indicators, Energy Imports as a percentage of consumption (EIMP), Reserve Margins (RMS), Electricity Fuel Diversity (EFD) and Macroeconomic Risk (Risk).

Reserve margins



Energy Security Index



Energy Trilemma – Sustainability (Climate)

Energy sustainability is the indication of its propensity to create damaging pollution.

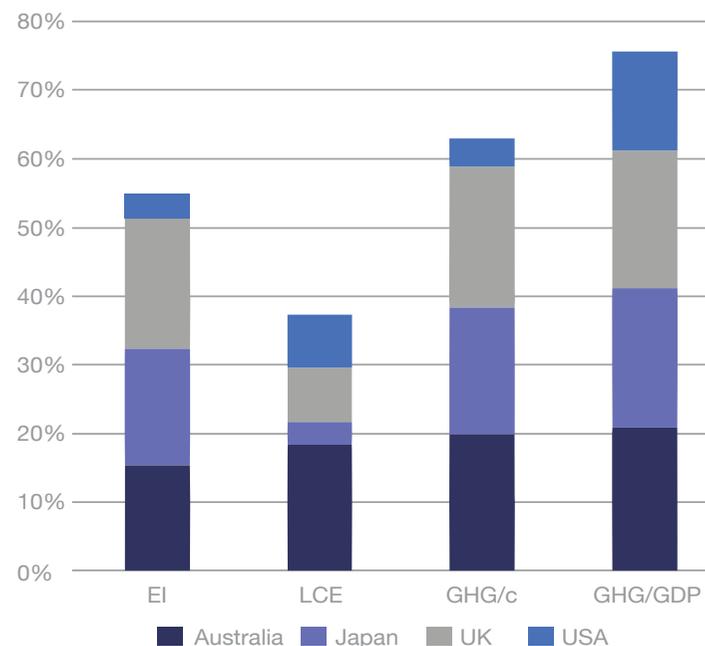
There is considerable debate linking energy consumption to the creation greenhouse gases to their influence on adverse climate conditions; whether long-term global warming through carbon dioxide, increased climate volatility causing extreme disruptive events, or increased pollutants. It is generally considered that increasing the likelihood and prevalence of such conditions is unsustainable and that measures to constrain or reduce them are highly desirable.

However, is it fair to impose very tough sustainability obligations uniformly or should there be some adjustment or compensation in the case of newer less mature economies? Since the newer economies tend to have less mature industrial bases their starting point is that in global terms they are lower contributors to climate pollution. It is only reasonable to provide some margin for them to catch up.

Energy Sustainability Index

Below is selection of countries ranked based on the Energy Sustainability Index. The Index is composed of 4 key sustainability indicators, Energy Intensity per Capita (EI), share of low carbon electricity in the generation mix (LCE), and Greenhouse Gas emissions per capita (GHG/c) as well as by Gross Domestic Product (GHG/GDP).

Energy Sustainability Index



Energy Trilemma – Affordability

Energy affordability is the accessibility and affordability of energy supply across the population.

Energy can be considered a public good and it is the national government’s responsibility to ensure that its entire population can access and afford energy. Energy is a good that can enable growth; without it, many daily functions are not possible. Energy allows for industrial growth, entrepreneurial activity and other public goods to be offered such as health and education.

Much of energy policy becomes centred around affordability due to political incentives, and is the reason why many energy markets and utilities are forced into competition; to maintain fair prices for the public. However, this position is complex because energy has traditionally been a major source of tax revenue to many national economies, helping to fund national socio-economic infrastructure.

Some energy sources have a cost directly linked to rate of consumption. Others might have high initial capex costs but then their marginal cost of energy produced might be low and almost at no added costs for extra energy created. Zero net energy schemes may be affordable on the grounds that overall they have no net energy demand external to their system.

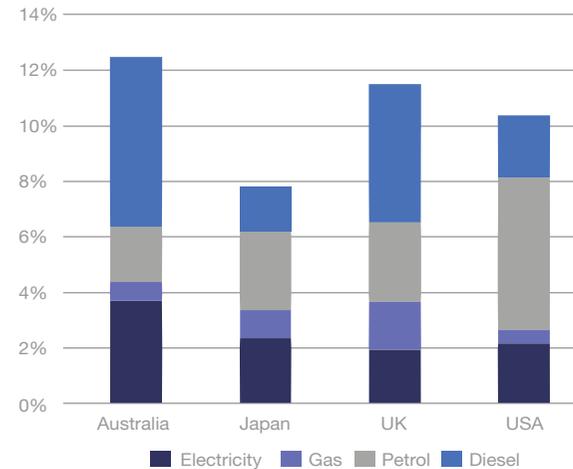
Energy Expenditure

Energy Expenditure is a key indicator in seeing affordability of energy in each country. Below the graph depicts the percentage each household pays from its income to different energy sources.

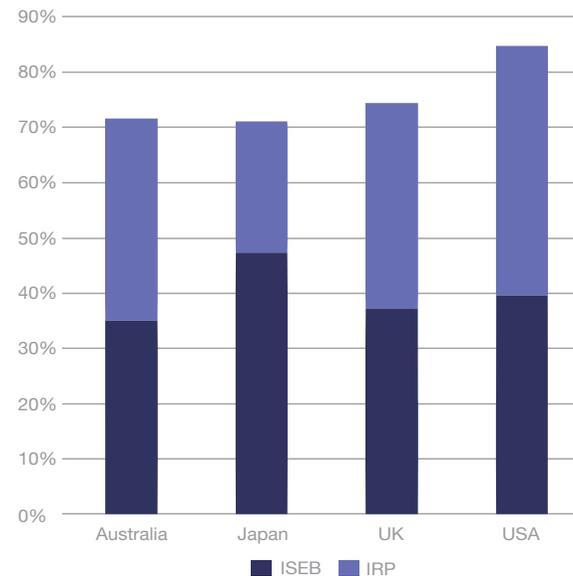
Energy Affordability Index

The Energy Affordability Index is composed of two key indicators of affordability, the % energy bills contribute to household income (ISEB) and industrial and residential retail electricity and gas prices (IRP).

Energy Expenditure:



Energy Affordability Index



Energy Trilemma – The Trade-Off

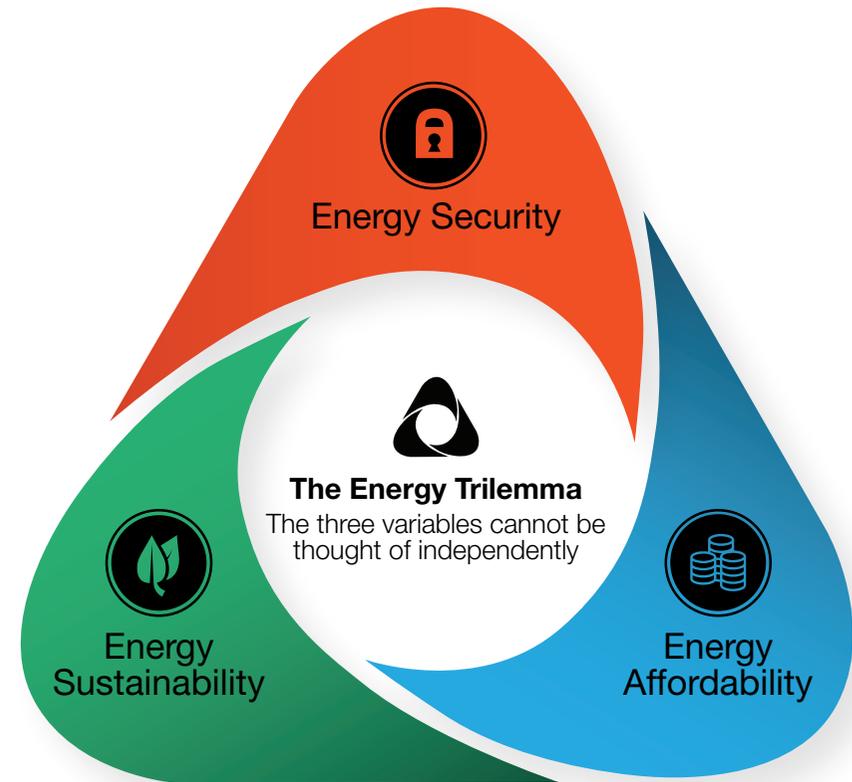
All three variables, security, sustainability and affordability cannot be thought of in isolation.

Low carbon and renewable energy requires significant capital expenditure and government support. So these more energy sustainable sources require a trade-off with affordability. Energy prices would rise to balance investment in renewables and the consequence would be more expensive energy.

Energy security implies that there needs to be enough power capacity to generate electricity to meet demands, both in terms of security of energy availability and in terms of network stability and frequency control. However, to strengthen capacity and security, the choice has to be made between cheaper power sources to maintain affordability or more expensive renewable energy which builds on sustainability.

If a country has poor energy infrastructure and low natural resources, it is forced to import expensive sources of energy and compromise energy affordability. Permitting it to import more affordable sources will compete with ambitions for more sustainable energy.

The examples illustrate the trade-offs each trilemma implies of the other two. When thinking of security, sustainability and affordability, the other two must always be considered for a holistic, integrated understanding of any energy problem.



The Arup Energy Trilemma Index (AETI)

The Energy Trilemma Index is a measure to see how countries are faring relative to each other in the three energy components of energy security.

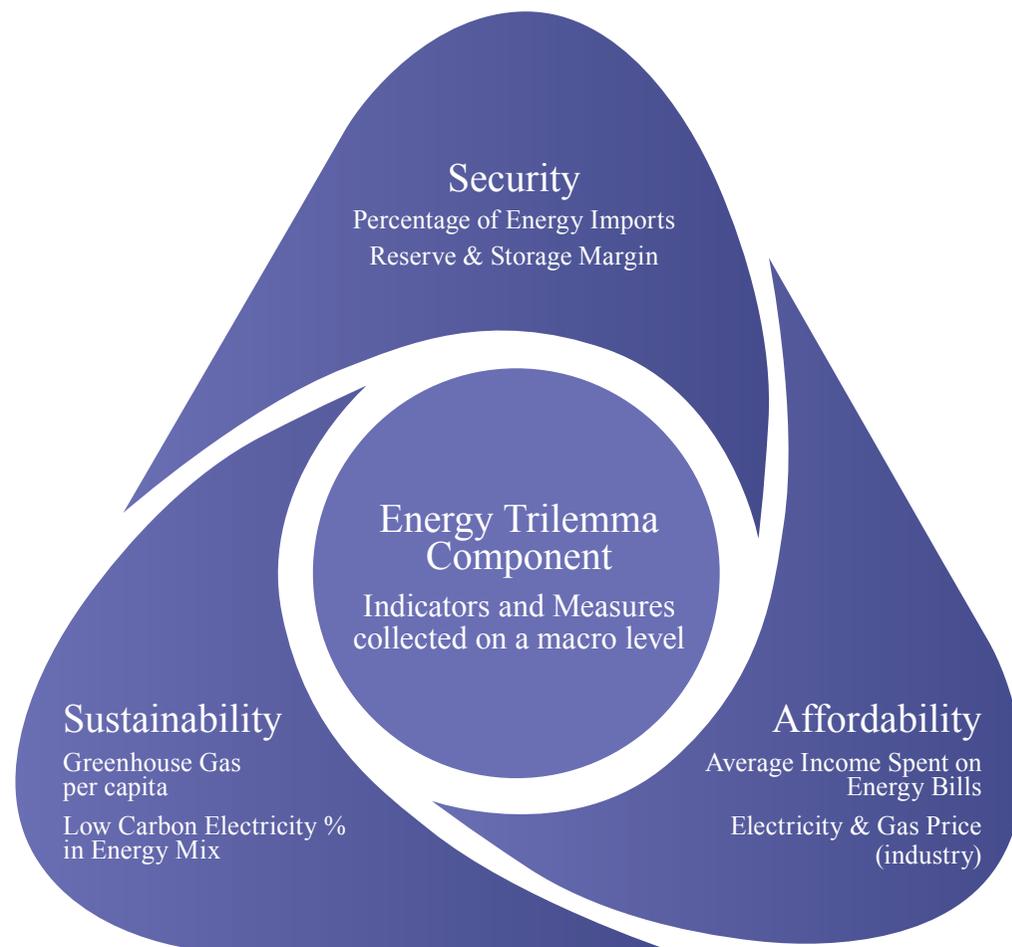
To assist judgements relating to the Energy Trilemma, Arup has developed a Trilemma Index model, leading to a Trilemma score.

The index seeks to inform decision makers about what gaps they have in each of the components and can be used to inform energy infrastructure and policy decisions.

The Trilemma score can be used as guidance on proposed energy policy frameworks and the design of new regulations.

The Trilemma Index currently consists of OECD countries, and is constructed using measures that quantify energy security, affordability and security objectives. A sample of measures is illustrated below to aid understanding.

A similar index model has been developed by Arup to consider scores for cities and companies. Cities can check their rankings against peers to see what they are missing on in each energy component, and companies can do the same. For cities, they can target long term infrastructure strategy using a trilemma framework and index. Companies would also be able to implement the index in a similar way, by advising their corporate strategy and future investments using the index as a measure of what they need to work on and what they are doing well.

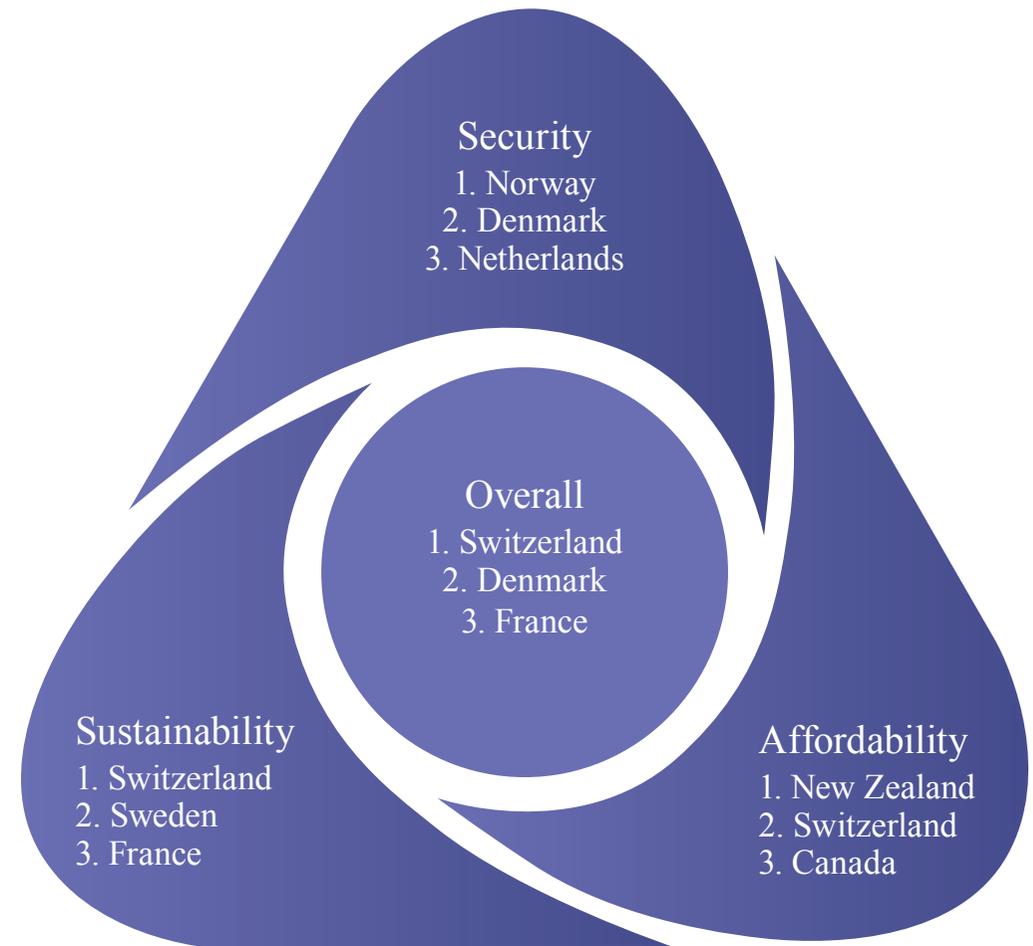


AETI – Results from the Index (Countries)

Based on 2014 AETI results, below are countries that performed well in each energy component and overall.

From the trilemma index results we can see that Switzerland, even though it didn't rank in the top 3 for energy security, it is still the overall winner. This is due to each country's relative weighting to the importance of each energy component. France, as we can see, if ranked third but they only rank in sustainability. This means that if France wants to better their ranking in the index they need to target energy affordability and energy security. This is useful to inform a country's energy policy in the future and how to effectively manage the trade-off required between energy sustainability, security and affordability.

Other countries can see the better ranking countries to understand how they can move up the scale, but also since the scale gives a relative weighting it doesn't put pressure on lower ranking countries to implement similar measures as others, but allows them to craft policy and regulation that is best suited to their own country's needs. This flexibility of the trilemma index is its strength and what makes it an extremely effective tool in policy making and energy strategy determination.

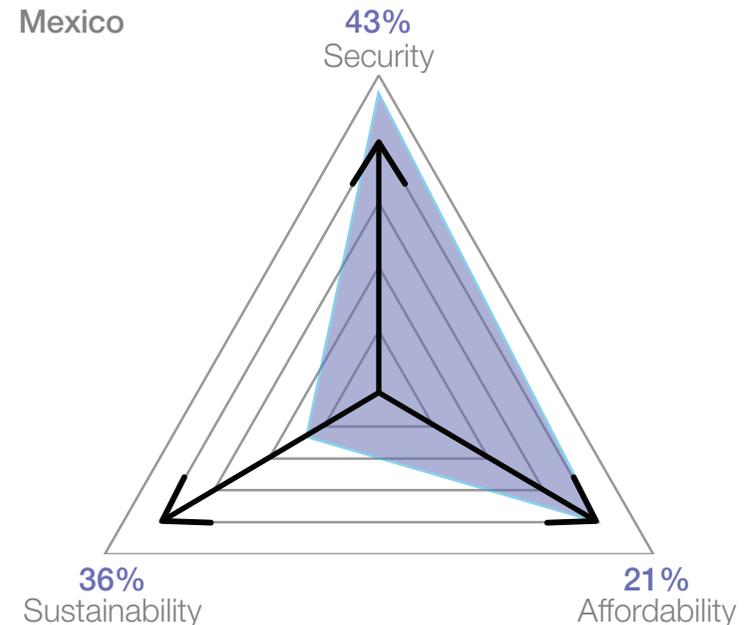
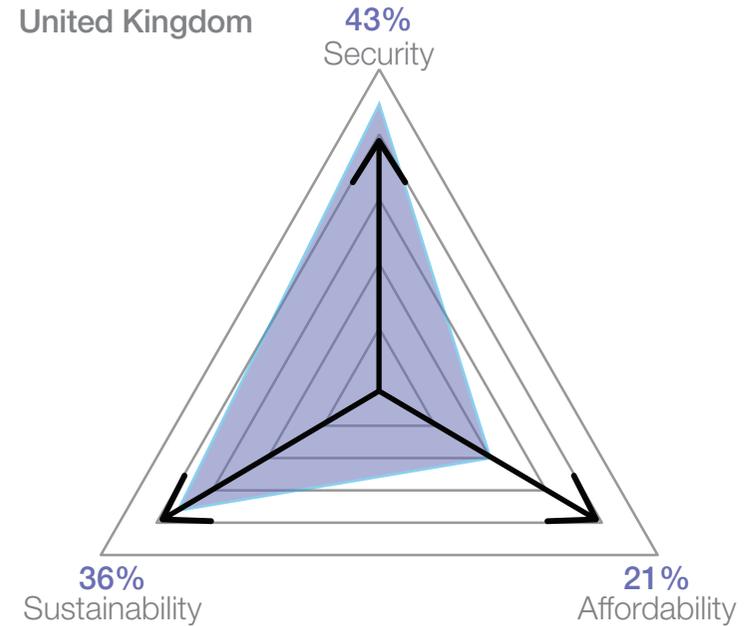


AETI – Energy Component Weighting (Countries)

When deciding how much each component counts toward the country's score, the immediate assumption is to split them equitably 33% each. However, each country would have different necessities based on their income level. A developing country might need to focus more on affordability whereas a country who is wealthy should place more priority on sustainability.

However, each country would have different necessities based on their income level. A developing country might need to focus more on affordability whereas a country which is wealthy should place more priority on sustainability.

The AETI has dynamic weighting for countries, where the sustainability component is considered by GDP per capita, security is based on oil & gas reserves per capita and affordability is the residual component. The illustration adjacent is an example of two countries and their dynamic weightings.

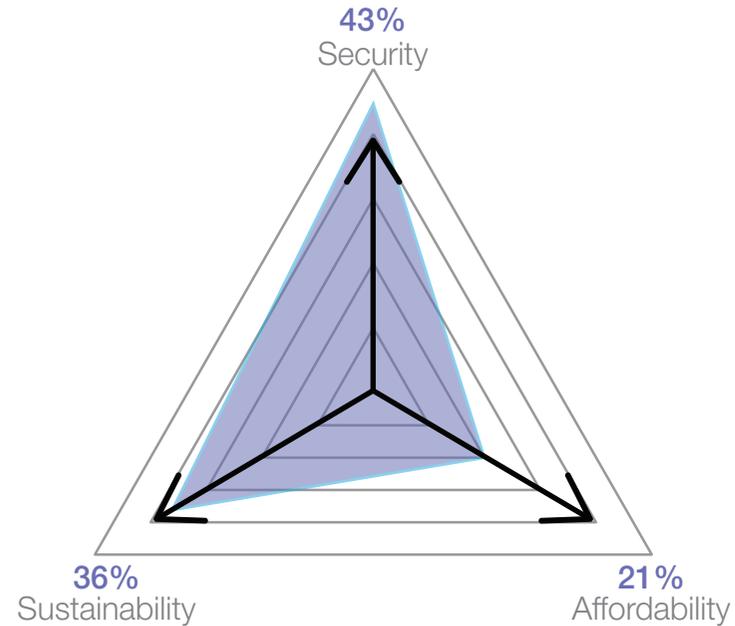


Trilemma Index – How to use it: (Countries)

The Trilemma Index can inform countries where they are lacking in terms of sustainability, security and affordability. For example, if we look at the UK's weighting based on its GDP and natural resources, its main focus should place a higher focus on sustainability and security. However in index results, they rank quite low in sustainability. This can be used to inform policy made by the UK.

Additionally, the index can be used to conduct cost benefit analysis of proposed energy infrastructure investment to see how a large infrastructure investment can impact a country's ranking in each component and in the overall index as well.

United Kingdom



Energy Trilemma Component	Ranking
Security	10
Sustainability	13
Affordability	10

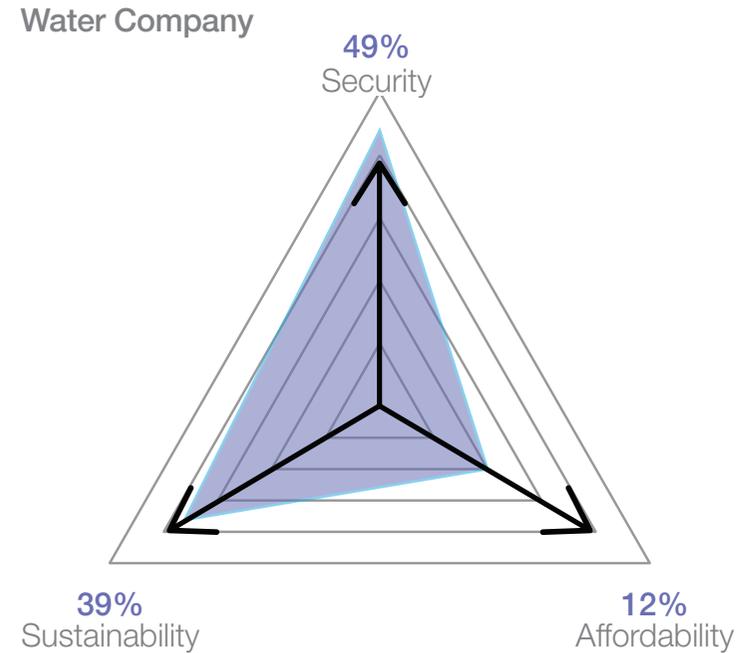
AETI – How to use it: Company Benchmarking

The Index can be used to guide corporate strategy both in terms of their branding / positioning and their investment choices – e.g. help identify opportunities where projects and programme benefit the Energy Trilemma outcome, the financial performance and socio-corporate objectives.

It can help identify opportunities where projects and programme benefit the energy trilemma outcome, the company’s financial performance and its socio-corporate objectives.

For example, a water company in the UK can see it’s ranking against its water competitors and use their ranking to advise strategy. If they are, in this example, behind on security of supply of water, they can devise their strategy to be oriented toward security and improve that score.

Energy Trilemma Component	Score against benchmark	Financial impact
Security	+ 20%	BB
Sustainability	- 15%	AA
Affordability	+ 35%	A



AETI – How to use it: Projects

The Index can be used to guide investors and energy-user companies in their project investment decisions.

The Index can assess the contribution that a particular project or investment programme may make to the country's or the organisation's energy trilemma.

The project can be benchmarked against other investment and therefore by associating a value to the energy trilemma improvement it could support strategic decision making around the location and the type of investment, particularly when assessing the impact of a portfolio or projects.

UK IREN & Benchmark Project Results

Rating AAB+

Single impact, not benchmarked Tidal

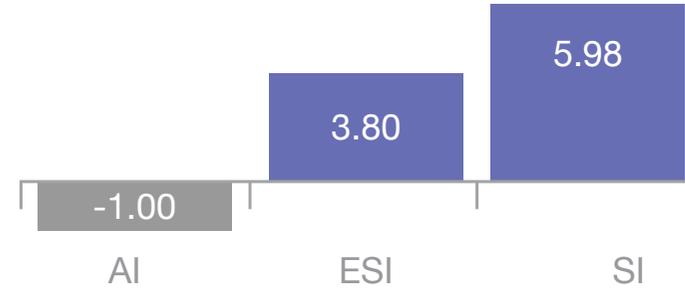
First letter: overall positive (A = significant positive, B = positive, C = negative)

Second letter: better than benchmark project (A = significant better, B = better, C = worse)

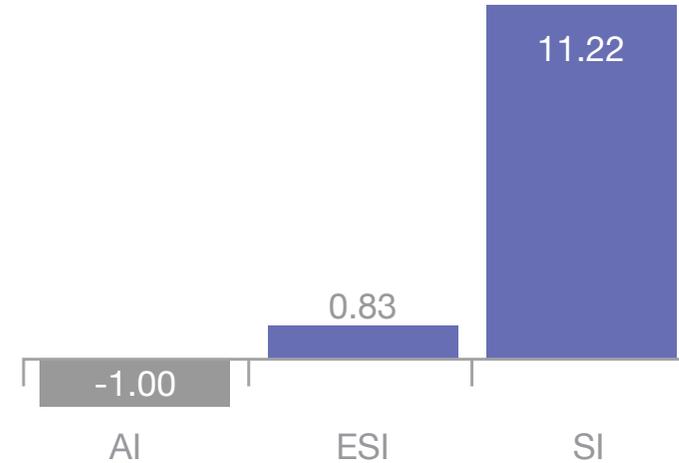
Third letter: all directions positive (A= 3 directions positive, B = 2 directions, C = 1 or none positive)

Annex: Future trend direction

Benchmarked to UK CCGT Project



Single impact, not benchmarked Offshore Wind



Trilemma Index – Framework for Clarity of Focus

The trilemma introduces a framework in how to view these three energy challenges together.

Previously, security, affordability and sustainability have been discussed by policy makers and industry separately, but these three components have strong influence on each other. Each requires trade-offs to make the other component better.

Rather than having international and national policy focus on each component, policy and decision makers need to think within the trilemma framework.

The trilemma framework can enable multi-dimensional thinking, allowing for policy to be tailored not just toward energy security for example, but also to see impacts on sustainability and affordability, and possibly improve decision making towards a more integrated approach.



Trilemma – Who Can Use It?

The Trilemma Index is a rating based on market dynamics of what a country or major organisation should do, by taking into account constraints such as capital resources and natural resources.

By setting targets for countries, it gives a quantitative basis for policy makers, energy industry professionals and countries a whole to see not just the impact of future decisions on the country but internationally as well, comparing it to its relative position in the index. Multi-national organisations can use it to assess the relative impacts and benefits of investing into different geographies.

It can also be used to look at project impact on a regional level. For example, when looking at the EU, countries must make security of supply decisions based on neighbouring capabilities. As for sustainability, there are EU wide targets, so countries within the EU can see where other countries stand against these targets and devise national plans accordingly.



The Energy Trilemma – Conclusion

The Energy Trilemma combines three key aspects of the energy markets and brings about a framework to discuss the issues holistically.

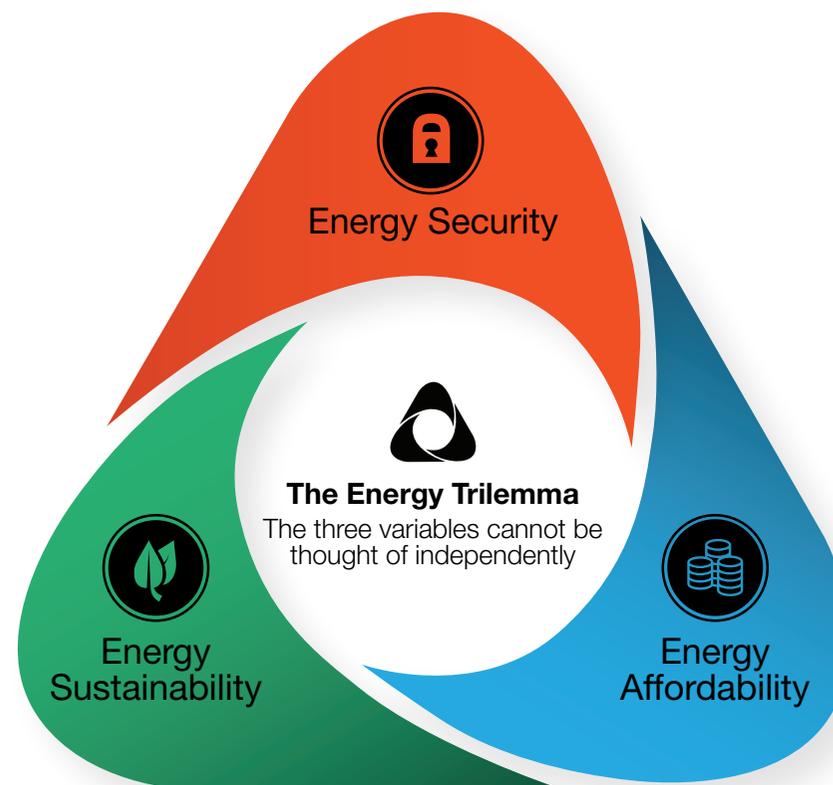
With demand for energy showing no signs of slowing down, and a pressing need for an international effort to combat climate change, the trilemma framework is more pertinent than ever.

The Arup Trilemma Index can be used for countries to observe their performance in each energy variable and can similarly be applied to Cities and organisations.

Arup's index can be modified to incorporate large energy-related infrastructure projects, to see the impact these projects would have on a country's ranking in affordability, security and sustainability.

It can also be extended to compare utilities' performances, such as water companies, to advise corporate strategy.

The Trilemma Index is an important tool and framework that major consumers of energy and organisations in the energy sector can use for an integrated view and informed decision making.



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