The Future of Energy

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About this report

Growing energy demand, as driven by population growth, "energy for all" initiatives and economic development, has led to an increase in greenhouse gas emissions. As sustainability becomes a worldwide concern, our industry must ask: How can advances in technology, policy change and behavior modification help solve this issue?

The purpose of this paper is to present our perspective on how the energy industry is expected to evolve over the next 20 to 30 years. We choose this timeframe with purpose, as projections for 2040 and 2050 allow ample time for the development of strategic plans while also capturing the necessary sense of urgency around climate change.

In preparing this report, we based our thinking on three widely accepted projections: 1. The world population will increase by 1.7 billion by 2040, mostly in urban areas; 2. Energy demand will increase by more than a quarter by 2040; and 3. The world at large is unlikely to meet the objectives set forth in the 2015 Paris Accord or similar energy agreements.

Advances in energy-related technologies combined with the digital revolution is expected to lead to significant change in how energy markets are operated. In addition, ongoing geo-political evolution, including the United States's emergence as the leading oil and gas producer, China's position as the worldwide energy leader, and ongoing volatility in the Middle East, will unquestionably influence the shaping of the future of energy.

While this report focuses on the energy future for select countries and regions, our analysis is intended to be applied more broadly. This study offers a global perspective on how the energy landscape may be influenced by the advent of new technology, shifting consumer behavior and political change.

The purpose of this paper is to present our perspective on how the energy industry is expected to evolve over the next 20 to 30 years. We choose this timeframe with purpose, as projections for 2040 and 2050 allow ample time for the development of strategic plans while also capturing the necessary sense of urgency around climate change.

This study is Capgemini's latest piece of research conducted on behalf of our clients and partners. Additional efforts include:

- World Energy Markets Observatory (WEMO), an annual report examining the electricity and gas markets in Europe, United States, Canada, Australia, China, India, and Southeast Asia. The document presents a current picture of the energy market and outlines transformation trends.
- Strategies for energy players, client projects that analyze the energy market and define the business strategy for the next three to five years.

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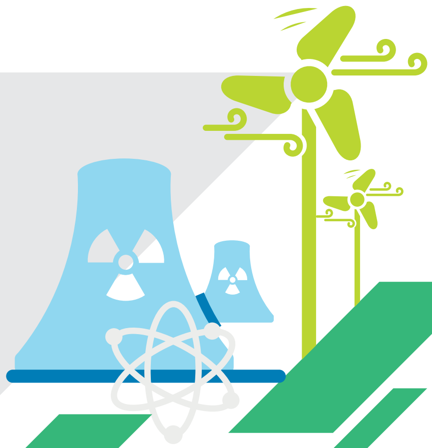

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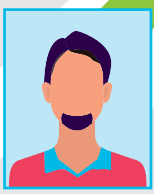
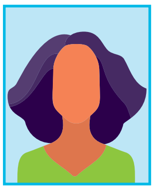
Placing a bet…

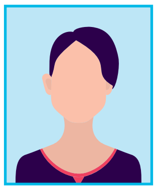
Welcome to 2049. Six Harvard alumni are meeting in Goa to review predictions they made thirty years ago about their country's energy future.



Arnold
from California, USA

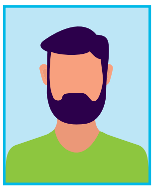


Rosa
from Montgomery Alabama, USA

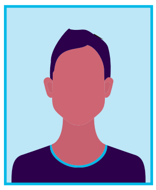


Marguerite
from Ho Chi Minh, Vietnam

Dinda
from Surabaya, Indonesia



Kelly
from Honolulu in Hawaii, USA



Talal
from Jeddah, Saudi Arabia

The Scenario: These six Harvard alumni each developed a vision for the future of energy for their respective countries. All documents were sealed and placed in a safe in Goa. Today we open these plans and reveal how they fared.

"Island Summer"
- Island context
- Decarbonation
- OECD countries

Applies to Hawaii, as well as Japan, overseas territories and elsewhere

Kelly
Hawaii, USA

"Resourceful as Ever"
- Massive fossil fuel use
- Huge environmental footprint
- Large investor in cleantechs
- Developed non-OECD countries

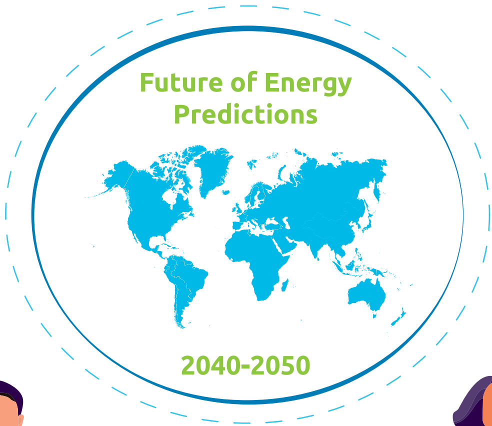
Applies to Middle East countries, China and elsewhere

Talal
Jeddah, Saudi Arabia

"Emerald Clean"
- Massive fossil fuel use
- Huge environmental challenges (i.e. local emissions, waste management)
- Developed countries

Applies to Indonesia as well as developed SEA countries, some African countries (such as Kenya, South Africa), Latin American countries, southern European countries and elsewhere

Dinda
Surabaya, Indonesia



"Green Expectations"
- Massive fossil fuel use
- Electrification partially achieved/limited infrastructions
- Developing countries

Applies to Vietnam, Cambodia and select Northern African countries

Marguerite
Ho Chi Minh, Vietnam

"California Dream"
- Decarbonation
- Environmental "hype"
- OECD-type countries

Applies to California, as well as Northern Europe and, to a lesser extent, Australia

Arnold
California, USA

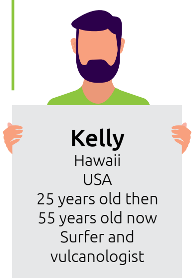
"Alabama Song"
- Fossil fuel reliance
- Conservative position towards environment
- OECD countries

Applies to Southern U.S., select Eastern European countries, Russia and, to a lesser extent, Canada

Rosa
Alabama, USA

Energy stories for the future

1.1. “Island summer”



Economy

Stable/slightly increasing energy needs for OECD countries, balanced by a goal to decrease energy consumption by 30 percent

- Mix of renewables portfolio to guarantee optimal affordability
- Clean transportation incl. electric mobility with “vehicles-to-grid/home” expansion
- Consumer behavior changes slowly for households and buildings but with many technology users appearing to gain more energy savings

Policy

Engaged environmental policies to stabilize energy needs and even reduce electricity demand by 30%

- The 100% renewable energy sources objective is achieved for 2040, as enabled through technology and geothermal capabilities
- Strong regulation for new technologies to ease market integration

Technology

- Oil ban
- The first state deploying hybrid generation (wind, solar, geothermal, storage, etc)
- “Enerdata” is massively deployed and AI will be deployed along the whole energy value chain
- Smart grid at scale

Resources

- No scarcity of certain raw materials
- Exploitation of geothermal potential

Kelly succeeded in imagining the future of energy in Hawaii. However, his predictions were not particularly high-risk given his awareness of Hawaii’s clean energy initiative, “transforming power in paradise,” which aimed to take the state from being the most fossil fuel-dependent in the nation (in 2008) to the first 100 percent clean energy state by 2045. Hawaii’s fully decentralized “Islands Top Energy System” is at the cutting edge of innovation in energy generation, storage, and management as well as security of supply. Notably, this process was achieved without significant cost increases. Political progress over the past 20 years helped the island become energy self-sufficient and has greatly improved its “System Average Interruption Duration Index (SAIDI)” KPI. Moreover, the state relies exclusively on renewable energy sources as of 2040 and is now focused on clean transportation, with the goal being to secure a zero carbon footprint in this areas as well.

Hawaii's energy model Transforming Power in Paradise has led to the creation of 20,000 net new jobs including Kelly's, who was able to balance his volcanology passion with protecting the planet.

Hawaii succeeded in "transforming power in paradise" thanks to four main levers:

1. A strong government policy which leverages the island's huge potential for renewable energy sources by using various economically efficient technologies.
2. The ban on some energy sources, including oil.
3. An energy efficiency program aimed at reducing electricity consumption by 30 percent, even as demand increases due to shifts in usage patters, including the adoption of electric vehicles.
4. Development of one of the world's most advanced grids, which maintained reliability and balanced intermittency while decentralizing generation.

In achieving its "power in paradise" objectives, Hawaii serves as an example to the rest of the world.

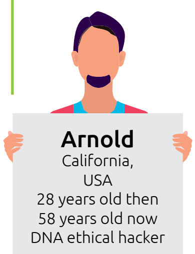
- The state was the first to deploy the smart grid at scale, which integrated local, small-scale power generation and storage units. As a result, multiple internationally recognized energy management software startups have launched within the state.

- Hawaii, along with Indonesia, has become a global reference points for effective geothermal energy technology, as well as hybrid renewable energy parks

Like many island residents, Kelly was required to adapt his thinking, habits and lifestyle to help meet the island's energy objectives. For example, he no longer owns a traditional car but relies on an autonomous electric vehicle for transportation. He has also given up the use of a jet ski in favor of a self-propelled electric surfboard.

Hawaii's energy model has led to the creation of 20,000 net new jobs including Kelly's position as a vulcanologist. He is proud that his beloved state has received multiple awards for energy innovation and is recognized as one of the most successful examples of energy transition in the world.

1.2. “California Dream”



Economy

- Stable/slightly increasing energy needs for OECD countries
- 100% of new vehicles in 2040 are H2 new electric mobility; expansion of vehicles-to-grid/home, smart energy flex and hydrogen development
- Consumer behavior changes slowly for households and industry but with many technology adopters appearing to realize more energy savings

Policy

- California will engage environmental policies to stabilize their energy needs
- Carbon prices will vary by state
- The 100% renewable energy sources objective is achieved for 2040-2050
- Strong regulation for new technologies will ease market integration (smart grids)
- European market deregulated. Potential deregulation California and similar states

Technology

No new nuclear implementation and no gas expansion in the energy mix (but Carbon Capture and Storage will be present in the industry)

- “Enerdata” and AI will be massively deployed across the whole energy value chain
- Significantly decentralized distribution network reduces state dependency

Resources

- No apparent global scarcity; local shortages of certain raw materials

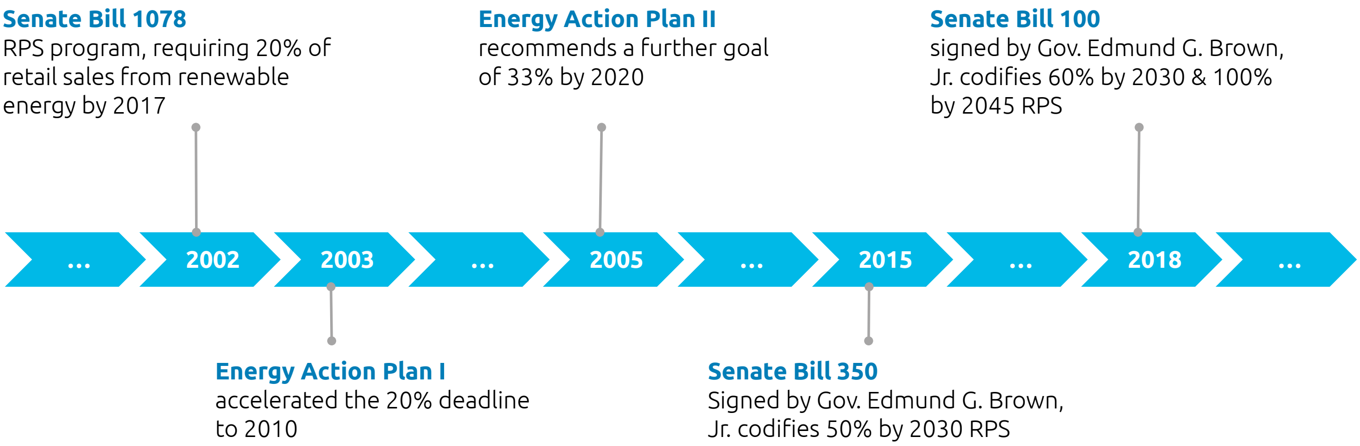
Arnold predicts that California’s strategy would work. However, no one could have foreseen how new technologies would reshape the entire energy market landscape.

Arnold predicts that those 30-odd years, consumer behavior gradually changed in households and industry, and many technology adopters appeared to benefit from greater energy savings. But despite energy efficiency improvements and environmental policies to stabilize demand, California’s energy demand increased slightly due to new products and services.

Electric mobility presents one of the most remarkable evolutions in the energy market. Beginning in 2040, California required 100 percent of all new vehicles to be powered by fuel cells. This shift is accompanied by additional changes, such as: expansion of vehicles-to-grid and vehicles-to-home; flexible smart energy initiatives; and hydrogen development.

This breakthrough was made possible by policy change and incentives, as well as Hydrogen popularity, which outpaced Tesla’s initial cornering of the e-mobility market. During the last 30 years, all elected Californian governments have set high carbon taxes and maintained the objective of 100 percent renewable energy sources. They also established Distributed Renewables as a statewide requirement, organizing markets with suitable values for load shifting and balancing against renewables development.

This breakthrough is attributed to policy change and incentives, as well as the growing popularity of Hydrogen.



Arnold predicts that a more progressive regulatory environment for new technology will help ease market integration. For example, all new new products and services sold in California must be smart grid compliant. As such, homes like Arnold's are fully connected to the smart city network through an 8G network and highly secure protocol. In addition, gradual deregulation of the electricity market has enabled the arrival of new players in the production market, as well as diversification of production and storage solutions.

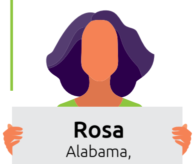
Moreover, California did not allow any new nuclear development and also forbade the use of shale gas. As a result, the energy mix in California is now composed of wind, solar and sea waves. Consequently, the distribution network became highly decentralized, resembling a collection of micro-grids. This approach has helped prevent any reoccurrence of 2019's widespread wildfires.

That said, California's energy transition success was highly dependent on the massive deployment of Enerdata and artificial intelligence (AI) algorithms along the entire energy value chain. In particular, California is using the second generation of quantum neural networks (QNNs) to solve real-time energy optimization problems and perform the required action on each node of the grid with complete autonomy.

California's energy model relies on many high technology components, the development and manufacturing of which requires a large quantity of rare earth materials. Shortages of certain raw materials has presented some challenges to organizations. However, the development of a high-performing recycling process has helped the industry avoid long-term, widespread shortages.

While Arnold had planned to work as a trader in the electricity market, that job no longer exists in 2049. Such roles were eliminated by the use of fully autonomous AI. However, Arnold noticed that the development of fast quantum DNA sequencing made cybersecurity an important issue within the industry. As such, in 2035 he established his own business selling individual services and products to protect against DNA hacking.

1.3. “Alabama song”



Rosa
Alabama,
USA
23 years old then
53 years old now
Digital farmer

Economy

- Stable / slightly increasing energy needs for OECD countries
- New electric mobility but no hydrogen development
- Consumer behaviors do not change for households and even regress in industry

Policy

- OECD states applied conventional environmental policies with classic regulations implemented to slow down energy demand
- 30% of renewable energy and a significant share of fossil fuel in the energy mix
- Few regulatory parameters for new technologies to ease market integration (smart grids) except for Carbon reduction
- Potential deregulation in California and similar states

Technology

- No new nuclear implementation
- Shale gas still expanding
- Carbon remaining coal for industry

Resources

- Local scarcity
- Global shortages of the main raw materials

Rosa’s forecast for the energy market in Alabama is remarkably different from that of Hawaii or California. Although Kelly, Arnold and Rosa all live in the same country, their states didn’t adopt the same energy strategies.

Unlike California and Hawaii, which defined its own ambitious energy transition strategy, Alabama decided to follow federal guidelines.

The local government applied conventional environmental policies, implementing standard regulations to reduce energy demand. In 2040, the energy mix still includes only 30 percent of renewable energy sources with the remainder of demand being served by fossil-fueled electricity generation. There was no new nuclear implementation in the state and shale gas is expanding. In addition, given the state’s fossil fuel resources, the local population is somewhat resistant change, given that the energy industry is one of the state's biggest employers. A wide variety of cost-competitive options for carbon capture, storage, and utilization has been deployed and could include post-combustion carbon capture and carbon dioxide utilization.

Energy demand in Alabama has remained stable since 2035, as is the case in many non-coastal states. Consumer behavior also hasn't changed for the majority of households. For energy-efficient industries, energy consumption started to decrease slowly thanks to use of new technologies. However, no significant improvements have been made in energy-intensive industries other than the early development of carbon capture storage systems.

Rosa thought that Alabama's energy market would be deregulated through diversified local energy production infrastructure. However, due to the reduction in regulatory parameters for new technology to ease market integration, the market model and operators haven't undergone significant change since 2020.

In the mobility sector, the share of hybrid electric cars and trucks has become more important than traditional vehicles. However, Alabama has not benefited from hydrogen car development. In fact, Alabama chose to invest only in hybrid technology, which is more suitable for local usage.

Alabama's situation is not unique. Several OECD countries have not embarked on an ambitious energy transition journey, likely because these areas still possess large quantities of cheap fossil fuel resources. In addition, many local people hold conservative views regarding climate change.

Rosa's best prediction was regarding her job. Having inherited her parents' farm, Rosa wanted to use new technologies to transform these properties into energy self-sufficient, organic farms, which is how she earns a living today.

Energy demand in Alabama has remained stable since 2035, as is the case in many non-coastal states.

1.4. “Emerald Clean”

Dinda
Indonesia
24 years old then
54 years old now
Underwater promote

Economy

- Southeast Asia’s energy demand grows by almost 2/3 by 2040 due to population growth and strong economic development
- Air-conditioning systems consume 40% of the electricity in Southeast Asia in 2040 at the present rate of consumption
- New electric mobility but no hydrogen development, and no deployment of V2G or V2H

Policy

- Deregulation process completed
- Loosening of regulations regarding environment policies
- Priority given to economic concerns. - No constraint on carbon prices
- More than 30% renewable energy sources in the 2040 energy mix, with fossil fuels retaining a significant share. Gas replaces coal
- Smart home deployment with centralized grids and expansion of leading digital utilities

Technology

- Expansion of geothermal capacities
- CCUS
- Little change in consumer behavior

Resources

- Various local resources: hydropower, geothermal capacities, hydrogen, shale gas

In her forecast, Dinda predicted an increase in energy consumption in Southeast Asia. However the region’s consumption still outpaced her estimates due to economic growth, an expanding population and “energy for all” initiatives.

For example, in Indonesia, the favorable socio-political environment prompted sustainable economic growth, as well as an uptick in the national birth rate. As a result, electricity consumption will nearly double between 2020 and 2050. The impact of global warming means that air-conditioning systems are consuming 40 percent of electricity in Indonesia and throughout Southeast Asia.

Unlike most OECD countries, which made energy transition a societal priority, Indonesia focused on economic development. The Indonesian government set energy efficiency targets to reduce the carbon intensity (CO_2/GDP) of energy but imposed no constraint on carbon prices.

Meanwhile, Indonesia is exploiting its natural resources. Most importantly, it has developed large-scale hydroelectric power plants to tap resources in the northern and eastern parts of the country.

The second biggest renewable power capacity to have been intensely developed is biomass, following 2016’s mandatory biofuel program. Biofuel production and domestic consumption have been encouraged mostly in the form of biodiesel.

The vast potential of Indonesia’s geothermal sector has been widely developed. Its current installed geothermal power capacity was already the world’s second largest 20 years ago and remained a priority for Indonesia through 2050. The country’s strong commitment serves to encourage developers’ participation in exploring the geothermal potential and to provide support through this risk mitigation facility.

One of the consequences of the demographic pressure urban areas is the emergence of offshore real estate—floating buildings moored at anchor points on the coasts of major cities.

As a en environmentally sustainable energy source, the geothermal sector is an integral part of Indonesia's overall energy security and independence. Nevertheless, this source cannot meet growing demand on its own and reliance on fossil fuels will remain.

Indonesia encouraged the development of clean coal fired power plants with additional CSS technologies. Since 2035, it has allowed private extraction of offshore natural shale gas. Today, the share of renewable energy is nearly 35 percent; a significant portion of remaining demand is served by fossil fuel, particularly the growing use of gas.

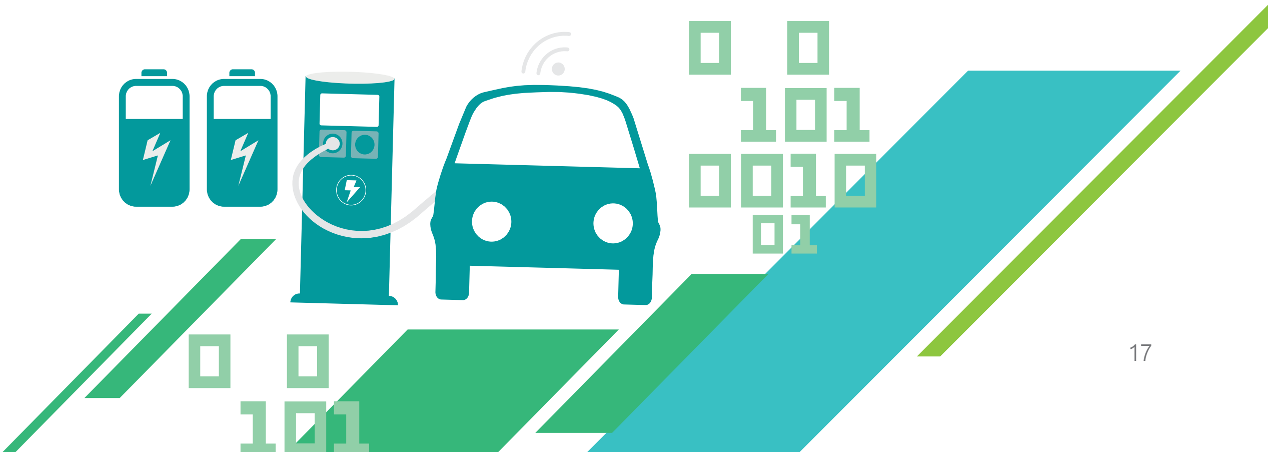
Hydrogen is combined with renewables to create different types of energy. This source is systematically distributed via a hydrogen energy hub. Energy storage technology now supports the stable supply of power year round by renewables, regardless of the weather. Further, in the case of natural disasters, it enables long-lasting energy supplies through stored hydrogen.

Nationally, the Indonesian energy production sector remained centralized as big utilities kept their historical role of electricity supplier in a largely regulated market. They adapted their offerings to meet smart buildings standards in large cities like Surabaya and have also adjusted production to align to changing usage patterns and behaviors, such as the intensive use of air conditioning. Thus, utilities have deployed technological solutions to be able to monitor the weather locally and adjust production efficiently.

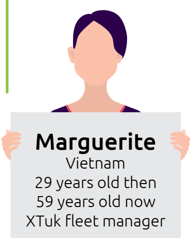
Finally, the Indonesian state government has maintained the power grid with the exception of a few islands. As a result, regulation of the network and management of its infrastructures remain centralized.

In Surabaya city, as in all large Indonesian cities, gasoline tuk-tuk cars and bikes are forbidden in the city center. Since 2035, only electric and hybrid mobility has been allowed.

One of the consequences of the demographic pressure in urban areas is the emergence of offshore real estate. These are floating buildings moored at anchor points on the coasts of major cities and connected to the mainland by fleets of autonomous electric shuttles. As the head of a company that manufactures and operates these vessels, Dinda has benefited from this economic boom. Her business is so successful that she exports electric boats to Venice, Italy.



1.5. “Green Expectations”



Economy

- Southeast Asia’s energy demand grows by almost 2/3 by 2040 due to population growth and strong economic development
- New electric mobility with vehicles-to-grid/home expansion. Hydrogen development initiated to complement e-mobility expansion

Policy

- Environmental policies with tougher regulations implemented to slow down energy demand
- Cap on carbon prices
- Consumer behaviors change slowly for households and industry
- Deregulation process initiated
- Around 30% renewable energy sources in 2040, with gas keeping the fossil fuel share significant
- Smart home deployment is ensured by new actors, with centralized grids and top digital equipment expansion

Technology

- New generation nuclear reactors including Small Modular Reactors (SMRs)
- Unconventional gas extraction expanding and Carbon Capture & Storage is maintained for industry

Resources

- Local resources: rare earth metals, unconventional gas

Marguerite’s predictions for Vietnam’s energy market underestimated the impact of a rapid transition policy. In fact, as in all Southeast Asian countries, greenhouse gas emissions increased dramatically during the last several due to population growth and economic development. In addition, domestic fossil fuel reserves were depleted far more rapidly than expected, necessitating expansion of renewables to meet consumption demand and compensate for the fossil fuel shortages. Finally, millions of people in the coastal regions of the country were affected by climate change and a significant portion of the population has been displaced.

Given this environment, most local authorities initiated policies with tougher regulations intended to reduce energy requirements, including a price cap on carbon prices. Vietnam increased its nuclear share by implementing multiple Small Modular Reactors (SMRs) financed by build-operate-transfer (BOT) schemes and by operating its own uranium reserves in the northern and central highlands regions.

Today, the average share of renewables in Vietnam is nearly 40 percent. In some regions the government has initiated the energy market deregulation process. As expected by Marguerite, Vietnam’s energy transition began relatively late and offered little in the way of preparation for the population or the economy. In fact, the development of off-grid renewable energy sources to fulfill rural electrification objectives was the key trigger for renewables development.

This rapid transition policy disrupted workers and communities reliant on traditional energy sources. It also failed to address long-standing gender and socio-economic inequalities, leaving behind an increasingly marginalized and disadvantaged population. Energy access inequalities are visible in many areas. In large cities, like Bien Hoa, we can

Marguerite and her partners designed an innovative biofuel synthesis process that makes a competitive substitute for E100 alcohol, the key ingredient in biofuel.

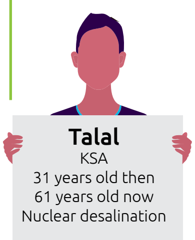
observe an expansion of new electric mobility with vehicles-to-grid and vehicles-to-home, which started with electric bikes and scooters. Biofuel development was initiated to complement electric mobility development. In addition, smart buildings with top digital equipment are being developed by many new actors.

In contrast, in the remote countryside and regions affected by climate change, people still use traditional mobility means and live in standard houses. Both consumer and commercial behavior and practices remain largely unchanged in rural areas.

Marguerite was very sensitive to the consequences of climate change and to societal inequalities induced by rapid energy transition. Thus, in 2040, she decided to set up a business in the form of a cooperative whose goal is to enable the poorest populations to produce biofuels for agriculture and transport usage.

Marguerite and her partners designed an innovative biofuel synthesis process that makes a competitive substitute for E100 alcohol, the key ingredient for biofuel. Thanks to local business angels' support, their idea was industrialized and is sold as bio-fuel synthesis kits. These kits are so successful that Chinese copies are sold all over the world.

1.6. “Resourceful as Ever”



Economy

- Energy needs to double by 2040, with an average growth around 5-10% per year, due to population growth and a strong economy
- New electric mobility with vehicles-to grid/home, and smart grid expansion.
- No hydrogen development
- Consumer behaviors do not change for households and regress in industry

Policy

- Few regulations implemented regarding environment policies, with priority given to economic concerns.
- No constraint on carbon price
- Around 30% renewable energy sources in 2040
- Deregulated markets, open value chain

Technology

- New generation nuclear reactors plus small modular reactors (SMRs). Shale natural gas extraction strongly expanded and coal gets a strong push
- Smart home deployment
- Centralized grids with top digital; top modern utilities

Resources

- Strong, diversified local fossil fuel resources
- Considering nuclear development
- Hydrogen should develop by using cheap low-carbon electricity
- Oil remaining a major resource

Talal gave careful consideration to his proposal for the future of energy in the Kingdom of Saudi Arabia (KSA). In 2020, his country was just beginning to consider energy transition. He wavered between two scenarios: 1) A rapid transition aimed at rationalizing the exploitation of oil reserves and reducing dependence on the oil market; and 2) A slow transition that aimed to continue to exploit and use oil and gas resources at the pace of the market, while leveraging the financial windfall to make a robust, well-planned social and energy transition. Talal chose the second scenario… and he was right.

Energy demand in KSA never stopped increasing because of strong population and economic growth, as well as global warming, which increased the need for air conditioning. KSA’s initial 2030 vision defined three major development axes:

- Raise gas production and distribution capacity.
- Grow the contribution of renewables to the national energy mix.
- Enhance the competitiveness of the energy sector.

Today the share of renewables in KSA is about 35 percent, missing the target by 15 percent. The government implemented few regulations regarding environment policies and priority was given to economic concerns. There is no constraint on carbon prices in KSA.

KSA's electricity generation capacity and natural gas demand has increased steadily as gas and renewables replace oil in the power sector. As a major fossil fuel producer, supplier, consumer, and subsidizer, KSA was urged to control its climate footprint, Growing demand has led directly to increasing levels of greenhouse gas (GHG) emissions and KSA was an early and significant victim of climate change, since its arid geography and harsh summer climate are highly vulnerable.

KSA finalized important decisions regarding its domestic energy use. Domestic gas processing has been optimized to free up more crude oil for export and reduce the amount used for oil burning.

Despite the delay in the development of renewables, KSA prepared the country's infrastructure for the future through the use of new technologies. As such, in 2045 the government started experimenting with energy market deregulation with an open value chain through a "remaining regulated downstream and deregulated generation" scheme.

The country set up a modern, fully centralized grid while simultaneously developing local microgrids.

Looking to mobility, vehicles-to-grid and vehicles-to-home, buildings, and smart grid expansion combined with hydrogen development have fully transformed the sector. Further, the landmark decision to substitute pure oil at the pump with hydrogen for domestic use has further accelerated this transition.

Talal was aware of the problems accessing water and wanted to work on improving access to drinking water in the regions most affected by global warming. He has achieved this through his business as an operator in the largest seawater desalination plant in the world. The facility is part of an energy complex consisting of nuclear power plants that produce electricity and heat, which are then used to produce hydrogen and desalinate seawater. Talal and his team adjust production between electricity, hydrogen, and water based on regional demand.

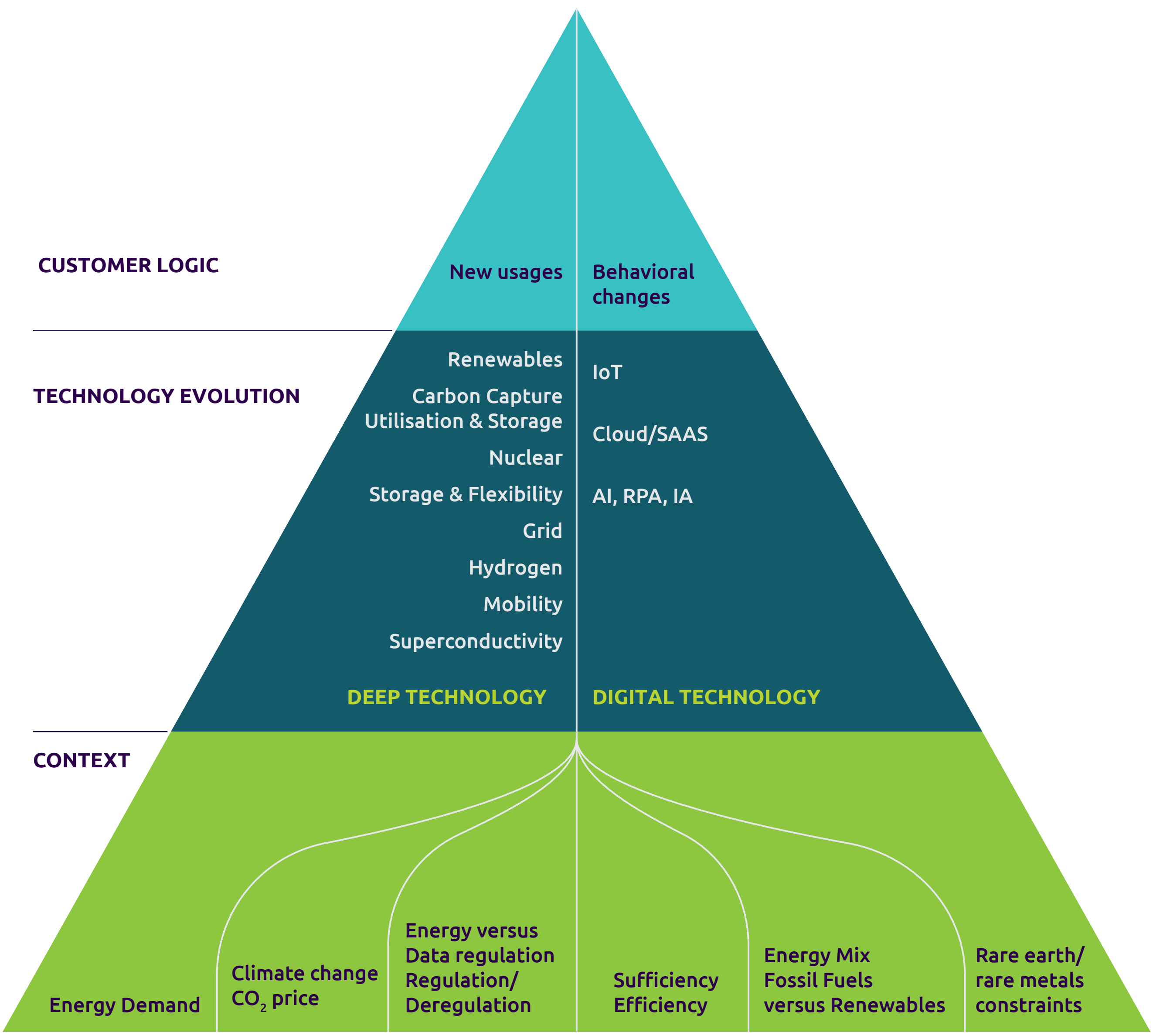
KSA's electricity generation capacity and natural gas demand has increased steadily as gas and renewables replace oil in the power sector.

2

Multiverse Energy

Our research identified 19 market drivers that will illustrate the contours of the energy market within the next 20 to 30 years. These factors are classified into four categories: context, deep technology, customer logic and digital technology.

Fig. *19 key factors defining The Future of Energy in a region*

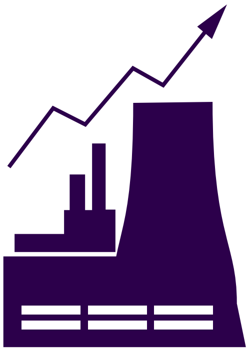


For each transformation trigger, we have identified transformation assumptions, from as-is resiliency to disruption.

Fig. *Key factors, possible changes and disruptions*

Disruption - 2040 - 2050 options Disruption + →

		Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
CONTEXT	Energy demand	Flat or decreasing in developed economies	Strong or flattening growth in non-OECD countries	"Power for All" initiatives in Africa		
CONTEXT	Climate change	Globally low CO_2 price plus regulations / Newtechs depend on industry goodwill			High CO_2 plus social regulations and development versus low CO_2	High CO_2 price and drastic regulations universally
CONTEXT	Energy sector & data regulation/deregulation	Maintain status quo or reverse		Value chains keep unbundling momentum in many regions	General unbundling	
CONTEXT	Sufficiency, efficiency, high & low tech	Same trend	Accelerated but insufficient growth		The real smart efficiency mix: low and high tech	
CONTEXT	Fossil fuels versus renewables mix	Continued reliance on fossil fuels	Significant share of fossil fuel	Near carbon free	100% renewables	
CONTEXT	Rare earths/metals constraint	China's demand rockets, and its domination over rare earths/metals is complete	OECD countries are regaining control		High tech progressing / substitution	
DEEP TECHNOLOGY	Renewables technology	Hard costs continue to decrease	Continuous technological progress	Major technological progress		
DEEP TECHNOLOGY	Carbon capture utilization and storage (CCUS)	Fossil fuels rocket; no CCUS	CCUS adoption limited due to cost	CCUS becomes widespread thanks to supporting regulations		CCUS becomes mandatory
DEEP TECHNOLOGY	Nuclear	Large nuclear above 1500-2000 MW	Smaller, safer 60-600 MW reactors			New fusion
DEEP TECHNOLOGY	Storage and flexibility		Progress but environmental and financial costs higher than conventional	Cleaner and cheaper storage	Completely clean and cheap electricity storage	
DEEP TECHNOLOGY	Hydrogen		H2 FC electrolysis for large-scale usages / specific use cases	Plus hydrogen (H2) for mobility and mixed in gas grids		Dedicated pure H2 grids for HH, C, mobility & I usages (if large industry usages cease)
DEEP TECHNOLOGY	Grid		Smart grids at scale for main operators	Microgrids as an alternative to existing infrastructures. No new grid, depletion of existing ones	Smart energy flex everywhere	
DEEP TECHNOLOGY	Superconductivity		Present developments - experimentations		Future developments	
DEEP TECHNOLOGY	Mobility	Limited trend (a few %)		Stronger growth – up to 20-50% mobility mix		Relocation and reurbanism
CUSTOMER LOGIC	Customer changes		Consumer led transition efforts	Total prosuming	"My energy, my way"	
CUSTOMER LOGIC	New usages	Averse to new usages	In favor of lighter & shared usages	Consumer becomes efficient prosumer		
DIGITAL TECHNOLOGY	IoT					
DIGITAL TECHNOLOGY	Cloud and SaaS					
DIGITAL TECHNOLOGY	AI, RPA and IA					



2.1. Context

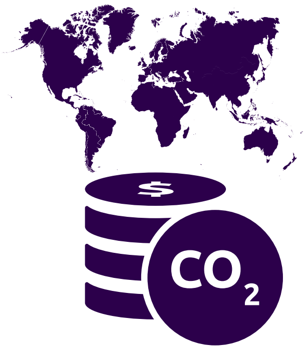
2.1.1. Energy demand

Energy demand is obviously a key factor in shaping energy markets. For this factor, we defined three hypotheses.

Flat or decreasing demand in developed economies	Strong or flattening growth in non-OECD countries	"Power for All" initiatives in Africa
• New electricity demand (e.g. data centers) will be compensated for energy efficiency efforts. • In many advanced economies, the link between gross domestic product (GDP) growth and electricity demand growth has weakened considerably in the past decade. • Efficiency measures have moderated growth in electricity demand in advanced economies. • Changes in economic structure in advanced economies will continue to lower demand. For example, in 2017 more than 55 percent of electricity demand in the industrial sector came from light industry, such as textiles and food.	• Chinese GDP is projected to grow by an average of 5.7 percent annually between 2015 and 2040 (IEA-2018 reference case). • Energy consumption in China will rise by 29 percent between 2017 and 2040 (BP scenario). • Middle East electricity demand will triple by 2050, powered by rapid growth of wind and solar energy. • In LATAM, total energy use is projected to expand by 60-80 percent through 2040 at an average annual rate of 2 percent (IDB, 2017). • Southeast Asia's energy demand is expected to grow by almost 65 percent by 2040 (IEA Scenario).	• Electricity demand in Africa is expected to nearly triple by 2040, reaching 2,306 TWh (BP Energy Outlook, 2018). • Africa's population is expected to increase by 42 million annually through 2050. • Higher demand due to electricity access and more rapid uptake of appliances contributes to an increase in "per-capita" electricity consumption. Triggers include rapid urbanization and substantial energy requirements for increased scale of manufacturing and water treatment.

Capgemini's predictions for 2040:

- While energy use seems to be gradually decoupling from economic growth worldwide, the two are still highly correlated in developing countries.
- Some geographies, such as the Middle East and LATAM, will represent a higher proportion of total energy consumption due to development in industry and transportation.
- Some uses will have a huge impact on global consumption. For example, at the present rate of consumption, air-conditioning systems will use 40 percent of the electricity in Southeast Asia by 2040.
- The disruption scenario can only be partially achieved. Even if consumption in sub-Saharan Africa increases by 150 percent from today, a portion of population will remain without access to electricity in 2030.



2.1.2. Climate change: CO_2 pricing and global climate governance

CO_2 pricing and climate governance are linked to the concepts of politics, economy, and sovereignty

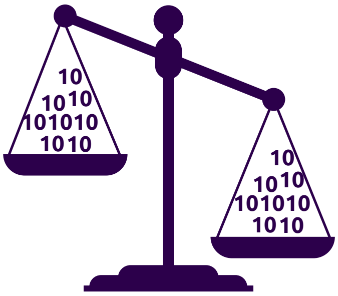
=	+	++
Stepping backwards: **Receding climate governance** **Business interests dominate** **Low CO_2 prices**	**Moving ahead:** **Some progress**	**Leaping forward:** **High CO_2 prices** **Balanced power**
• Global climate governance recedes, along with multilateralism and the role of the United Nations. • Major countries prefer to defend their own interests; a bilateral approach is, at best, secondary. • The Paris Agreement remains empty rhetoric. • Corporate interests influence and outweigh sovereign power, both in democratic and authoritarian systems as well as in international trade agreements. • The “rescue-by-technology” concept, along with an economy and way of life based on intensive consumption, remains the dominant climate motto backed by business, finance, citizens, and governments, despite scientists’ warnings. • In 2040, as in 2018, 50 percent of energy from fossil fuels attracts neither implicit nor explicit taxes (i.e. carbon tax or emissions trading schemes) and 40 percent is taxed below 30€/TCO_2.	• Explicit carbon pricing (ETS and carbon taxes) affect 50 percent of all CO_2 emissions progressively. • Explicit carbon prices increase to 30-50 €/TCO_2 globally. • Subsidies to fossil energies disappear by 2040. • Maritime and air travel start paying small energy taxes as is customary in other sectors.	• International trade and multilateralism have accepted explicit carbon pricing in the 50-80€/TCO_2 range, covering over 80 percent of all uses and trades beyond road transport. This includes coal, gas, aviation, and maritime transport. Tax is applied on the same basis to all industries, as well as commercial and residential sectors in all regions.

= Stepping backwards: Receding climate governance Business interests dominate Low CO_2 prices	+ Moving ahead: Some progress	+++ Leaping forward: High CO_2 prices Balanced power
• Only road transportation keeps taxes over 80€/TCO_2 on average, as in 2018. • Maritime transport (see 2020 MARPOL) and aviation remain globally untaxed. Aviation carbon pricing through emissions trading schemes (A-ETS) or reduction schemes (CORSIA) remain voluntary and negligible in terms of flight costs, actual achieved carbon savings and offsetting. • Coal remains largely untaxed, when not subsidized. • Subsidies for fossil fuels bounce back. After halving from 2013 to 2016 to $270B, they increased to $300B in 2017. Subsidies persist even in 2040. • Industry, commercial, and residential sectors keep energy costs covered at only 30 percent of the total cost due to implicit and explicit carbon pricing. • Carbon taxes and emissions trading schemes remain in the 10-30 €/TCO_2 range, far below the 40-80 €/TCO_2 needed to massively foster usage sufficiency, technology efficiency, and transition to sustainable energies, economies and business models.		• Sovereign power outbalances business power – yet a stable framework enables long- term fairly profitable business, though with reduced growth.

Capgemini's prediction for 2040:

Between 2015 and 2025, the world energy market will most closely resemble scenario one. Yet contradictory forces may reasonably lead to the middle scenario. The third scenario, which is more in line with a scientific view, is unlikely.

[1] Source for 2018 starting point: OECD Effective Carbon Rates 2018 , WB State and Trends of Carbon Pricing 2019, Capgemini Invent analysis



2.1.3. Energy sector and data regulation/deregulation

Regulation, or so-called "deregulation," has implications for the electricity value chain and market design, as well as synergies between electricity, natural or synthetic gas, and local heating and cooling district networks and storage.

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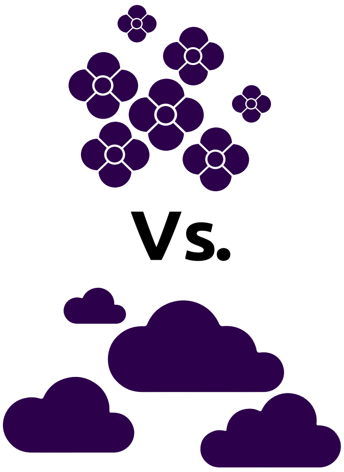
Integrated power	**Unbundling power and data**	**Interwoven power, gas, district networks, and data**
• The status quo remains or there is even reverse movement from deregulation back to integration of the electricity value chain. • Consumers get tired of complex competitive energy markets without price decreases. They welcome going back to a single energy supplier. • Incumbent network operators fight local energy networks. • Regulations keep data vertically locked. Smart cities and open data have difficulty finding operating models as well as business models.	• Electricity value chains keep the unbundling momentum in many regions. • Power, gas and district regulations are kept fully separated, but start being coordinated at both global and local level. • Regulation prompts transport and distribution network operators to improve data circulation. This includes establishing personal data protections and creation of new business opportunities through data.	• General unbundling everywhere. • Regulations intersect data, power, gas, and local district networks, so that real synergies, optimizations, or choices are enabled, eradicating false or inefficient competition between energies. • Local competitive public service concessions can rebundle relevant consortia, mixing data, energies, networks, generation and energy services. This can only be made to get quicker and stronger local gains in terms of CO_2 emissions, energy spent and comfort. This new full integration is allowed only locally (max. size = district or small city) and only for relatively short periods.

Capgemini's prediction for 2040:

All three scenarios are possible. An alternative regarding data (not examined here) is that individual data is widely shared with little or no regard for privacy.



2.1.4. Reducing energy and waste: sufficiency, efficiency, high tech, and low tech

Energy savings are the first lever on the path to sustainability. They are derived by avoiding the unnecessary use of energy (sufficiency) and making progress in technology (efficiency). A key indicator is the progress made in the energy intensity of the economy, rated as the energy spent by $1K of GDP.

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Today's trends persist	**Accelerated (still less than needed)**	**The real smart efficiency mix: low and high tech**
• Energy intensity improvement remains at 1-1.9% annually. • Progress is boosted by industry and is based on technology efficiency. • Technology progress is significantly offset by the rebound effects: customers and industry both want growth, i.e. more, larger, quicker, bigger, more expensive products, homes, cars, buildings, etc. • Energy regulations remain driven by verticals (building materials, construction, transport, etc.) and somewhat restrained to protect growth and "Get More for money" product value propositions (more quantity, more volume, larger, heavier, more luxurious products…). • "Digital Everywhere" saves energy through automated sufficiency and technical efficiency.	• Energy intensity improvement reaches 2-2.9% annually. • Each use is treated separately. Sufficiency and efficiency are both addressed systematically. • Regulations become more stringent, but also provide a clear, secure, and stable business environment. • Digital consumes less materials and generates less waste: • Video hypergrowth is stabilized, even with the development of 5G • General downsizing • Efficient coding • Smaller devices • Self-energy microwatt energy capture (light, sound, vibrations), etc.	• Energy intensity of economies and societies improves 3-4% a year, as needed to comply with global sustainability challenges. • Holistic horizontal approaches: Buildings vs urbanism, (less commuting, a more circular economy, and energy synergies within districts, etc); Manufacturing vs markets (simpler logistics, relocation). • Low tech and high tech are mixed smartly: use short-life high tech selectively as it requires a lot of grey energy, raw materials, and waste management; implement low tech whenever appropriate ((classic long-duration equipment and grids, simple robust cars, well-planned homes and buildings, etc.).

Today's trends persist	Accelerated (still less than needed)	The real smart efficiency mix: low and high tech
• Digital, clean tech, high-tech, electric/electronic equipment, and IoT have short lifespans and high stock rotation, resulting in adverse global impacts on raw materials and waste.		

Capgemini's prediction for 2040:

We anticipate an intermediate scenario between the] first two columns. The disruption scenario looks more like a utopian dream, due both to the inertia of physical cities and assets, as well as lagging interest by consumers, the financial community and government entities. That said, the disruption scenario may occur on a local level.

2.1.5. Fossil fuels versus renewables mix

To study the development of renewables, Capgemini proposes four alternatives affecting the worldwide mix.

−	+	++	
Fossil fuels will maintain a 65% share in the worldwide energy mix	**Gas keeps the whole fossil fuel share significant (58% by 2040)**	**Approaching a carbon-free worldwide mix**	**Achieving 100precent mixed renewables based on accelerated deployment**
• In this option, the world will continue to rely primarily on fossil fuels even though renewables are expected to be a fast-growing energy source. • This scenario suggests a "back-to-coal" political statement and some of China's coal restrictions lapsing. • It implies that "clean coal" is able to compete with nuclear power on the basis of near-zero emissions for base-load power (+CCS).	• Existing policies remain the same. • Use of renewables increase but not significantly. • Globally, shale gas production is expected to grow from 5,563 billion cubic feet in 2016 to 8,000 billion cubic feet in 2024 at a CAGR of 4.7 percent for the same period (Market Watch, 2019). • This so-called "gas glut" and development of LNG terminals will have a significant impact in the U.S.	• The fossil fuel share (in TWh) falls from 65 percent to 20 percent in 2040 with renewables (IEA, 2018 & 2019) • This scenario suggests wind and PV prices continue to fall. • Smart grids and batteries stake out a more important position in allowing greater flexibility and speed in deploying renewables.	• This option is inspired by the radical political trend initiated by 59 countries (incl. Australia), 72 cities, and 63 regions/states (incl. NY, California) all adopting a 100 percent RE objective by 2040. • In this scheme, besides a continuing fall in wind and PV prices, the implication is that technology and infrastructure able to support that amount of wind and solar can also be put in place within that time frame.

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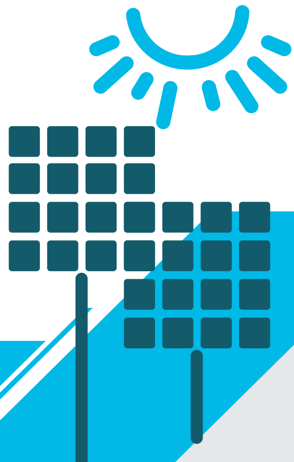
Fossil fuels will maintain a 65% share in the worldwide energy mix	**Gas keeps the whole fossil fuel share significant (58% by 2040)**	**Approaching a carbon-free worldwide mix**	**Achieving 100precent mixed renewables based on accelerated deployment**
• Fossil fuels are still expected to account for around 65% of the energy mix. • Coal is getting a strong push, progressively replacing the nuclear share. • Liquefied natural gas (LNG) is the trigger to broad-based future growth. • Natural gas continues to outperform coal and oil.			• Installing solar PV and wind 4-5 times faster per capita than China. • Straightforward deployment of off-the-shelf storage (pumped hydro and batteries). • Stronger interstate high voltage power lines used to stabilize a fully renewable energy grid at low cost through accelerated digitization. • Microgrid development and expansion of distributed energy schemes.

Capgemini's predictions for 2040:

- We are optimistic about achieving an intermediate scenario where fossil fuels (mostly gas) remain part of the energy mix while renewables expand.
- Despite the continuing growth and falling cost of renewable energy sources, fossil fuels will remain the cornerstone of growing energy consumption. The gas glut (mostly shale gas) will position gas as a major resource (and a natural substitute for coal, as gas is considered a clean fuel in all emerging economies). New combined cycle gas turbines (CCGTs) will support cleaner production.
- Renewables will remain the fastest-growing energy segment due to technology enabled cost reductions and political backing.
- While a large grid integrating 100% renewables will prove difficult to manage, we are extremely interested in hybrid farms and smart grids that are responding to this concern. Innovative hybrid projects assembling renewable generation and storage could definitely be a trigger for additional renewables development. Some notable pilots at this stage include: the Kennedy Energy Park in Queensland (Australia), the Advanced Clean Energy Storage project in Utah (USA), the Île de Sein Energies project in Brittany (France), and the wind-solar-PV-battery hybrid project known as the Meru County Energy Park (Kenya).

2.1.6. Rare earth / metals constraints mitigation



The resources category is highly correlated to the economy and technology categories. Depending on the rate of economic growth and use of new technology, we may face a shortage of some rare earths, with consequences for economic growth. Capgemini defines three alternatives for this "resource" category.

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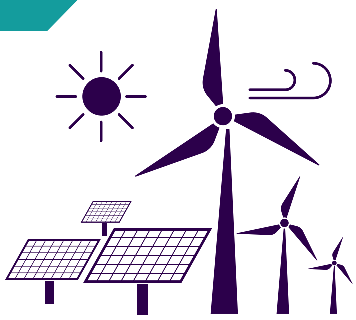
Demand rockets in China, securing China's dominance in rare earths	**OECD countries regain control**	**High technologies progressing/ substitution of rare earths**
• By 2030, demand for rare earth elements is expected to increase by 200-300 percent, as led by a surge in Chinese demand. • China will possess more than 70-80 percent of minerals reserves by 2030, as compared to 45 percent today.	• Countries that can afford to increase their domestic rare earth production will do so. • Recycling – a significant source of rare earth minerals – becomes a lever within a structured market. • New technologies help achieve a better balance between low tech and high tech through less use of rare earth materials • Geopolitical pressures are declining.	• Low technologies using rare earths have reduced considerably. • Resources are used with more restraint. • Recycling is part of the supply chain.

Capgemini's prediction for 2040:

As we observe changes in OECD countries' rare earth investment policies, we anticipate an intermediate scenario. For example, the United States is actively stockpiling key materials and is exploring, developing, and processing more rare earths.



2.2. Deep Technology

2.2.1. Renewables Technology

Renewables technology has been improving faster than anticipated and has helped lower associated costs. Three milestones for accelerated progress are highlighted here.

Hard costs continue to decrease	Continuous technological improvement	Major technological progress
• Hard costs are continuing to fall thanks to decreasing material costs and an increased ability of cells to capture light/wind. • Light energy conversion is improving: – 20 percent currently – 32 percent theoretically due to present technological improvement – 46 percent potentially with four layers	• Some new materials like perovskite, which are used in the production of solar energy, could lead to cheaper and more efficient photovoltaic cells; unlike today's silicon cells, they won't degrade rapidly in heat. • Proliferation of next generation wind farms will be achieved - small wind power, multirotors "bladeless" wind power units, ... - with better output and mitigation of externalities	• Artificial intelligence will help to tackle negative externalities and to considerably increase renewables' performance by integrating a multitude of data sources about the weather, the environment, atmospheric conditions, and how renewables' plants and power grids operate. It will combine a multiplicity of forecasting models to increase the power plant unit output. • Solar operations will use machine data mining to forecast atmospheric conditions and weather, including the amount of precisely timed photovoltaic energy produced at power plants:

–	++	+++
Hard costs continue to decrease	**Continuous technological improvement**	**Major technological progress**
• The 2019 Portuguese auction, which attracted a world record bid of €14.8/MWh for solar could be a reference price for the entire industry in the future. • New potential will be gained; light energy conversion improvement makes low-light geographies/areas eligible for solar energy. • Wind turbines continue to increase in height, efficiency (performance ratio improvements), availability, and in various other ways (i.e., noise, losses, connection).		– Calculating how much sunlight falls on a roof during a year and converting the data on sunlight into energy and calculating the potential cost savings. – Including multiple components based on observations, either measured at the site or remotely via satellite. – Increasing energy production of solar farms, thereby enabling faster operations and easier maintenance. • Wind technologies will be considerably improved with precise, detailed predictions: – Using AI to enhance wind turbine efficiency. – Correlating past weather and turbine operation data to predict output in advance. – Making individual forecasts by turbine, as propellers at different heights face different wind speeds. – Stopping turbines for maintenance checks on low-output days, raising overall output.

Capgemini's predictions for 2040:

- Renewable technology will improve more significantly than expected. This scenario has been confirmed by the present facts, including solar generation hard costs (i.e. equipment) and soft costs (i.e. labor or costs for permits) are about equal in the U.S. The potential 2020 cost is $48/MWh.
- There is much room for technological improvement in both solar and wind power plants.
- But the next big move is the integration of industrial AI to model, simulate, and deploy transactive energy solutions for improved system design and better monitoring of renewables. It will help mitigate some externalities, such as disturbances or environmental impacts, and considerably improve the operational performance of renewables. Renewables solutions will be sited in new geographies, better integrated into their surrounding environment, and physically closer to their customers.
- Governments and authorities will simplify and shorten all procedures; Installation will be better managed, resulting in moderate but real decreases in soft costs.

2.2.2. Carbon Capture Utilization and Storage (CCUS)

Current use of Carbon Capture Utilization and Storage (CCUS) has been limited to pilot programs and specific local usages, such as enhanced oil recovery (EOR). We propose four options ranging from a “no CCUS” to an “all CCUS” scenario.

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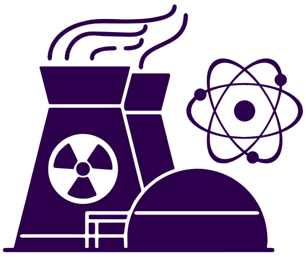
Fossil fuel use rockets; no CCUS	**CCUS limited by cost**	**CCUS becomes widespread thanks to supporting regulation**	**CCUS becomes mandatory**
• Fossil fuels have a 65-70 percent share of the energy mix. • Advances in classical technologies such as CCGTs or fluidized bed combustion improve cleanliness. • CCUS won’t emerge as a key technology.	• CCUS is viewed as a niche technology. • CCUS represents 10 percent of power generation units.	• If regulatory schemes are effective and/or the CO_2 price exceeds 50-100 $/t, CCUS could penetrate: – Coal generation – Industrial processes – CCU with H_2 for liquid fuels	• CCUS becomes the norm for each high carbon generation unit thanks to strong political willingness and mounting social pressure. • Technological progress in CCUS helps to a achieve fully competitive cost below 40 to 50 $/T$CO_2$.

Capgemini’s prediction for 2040:

The world has a strong need for CCUS within the context of the current warming scenario of 1.5-2°. This vision requires positive regulatory signals, such as CO_2 price and strong public acceptance. At the same time, it also necessitates significant technological improvement to achieve a CCUS cost of 60-100 $/t CO_2 by 2030/2040.



2.2.3. Nuclear

For nuclear, we propose three alternatives for technological evolution: New Nuclear, SMRs and Fusion.

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New Nuclear Large nuclear above 1500-2000 MW	**SMRs Smaller, competitive 60-600 MW reactors**	**Fusion based nuclear plants**
• Nuclear keeps a 10 percent share of the worldwide mix by 2030 (IEA scenarios, 2019). • The cost of new generation reactors such as third and fourth generation EPRs is maintained at 80-100 €/ MWh, so long as scale effects conditions are achieved. • • The competitiveness of nuclear energy against fossil fuel generation rises due to CO_2 penalties and the need for large storage capacity. • Some key success factors may enhance competitiveness and social acceptance, such as: – Steering a CAPEX-intensive industry. – Managing large-scale projects and scaling up to accumulate large reactors. – Complying with high safety standards. – Offering solutions throughout the reactor cycle: from design to construction to safety and training, as well as waste management/dismantling.	• Small modular reactors (SMRs) are meant to be manufactured and assembled at a central factory location. • These advanced technologies present multiple advantages: – Long-term energy security – Less nuclear waste – Modularity (60 MW modules that can be twinned up to 600 MW). • Several designs exist for SMRs, ranging from scaled-down versions of existing nuclear reactor designs, to entirely new generation IV designs (with restricted area access according to the design). • SMRs are operational in the UK and there are big plans for SMRs in Canada. Many designs have been presented to regulatory bodies for assessment. • There is stop-start deployment in Africa, where this kind of project remains expensive.	• New fusion technologies are appealing but their potential is limited. By 2040-2050, most of the projects are expected to have ended. • Traveling wave reactors are decommissioned by this time. • Funding to build ASTRID, a prototype sodium-cooled nuclear reactor that would use depleted plutonium as fuel was withdrawn in 2019. • Six thorium-based nuclear power projects, fueled primarily by nuclear fission, are operational.

Capgemini's prediction for 2040:

New nuclear's pitfalls must be tackled to increase its potential. While operation of third generation reactors implies some restriction in market access, SMRs have greater market potential than third generation plants due to lower capital investment.

2.2.4. Storage and flexibility

The combination of reduced consumption with more intermittent production increases the need for flexibility on all levels. Will storage and demand response answer the new flexibility challenges?

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Progress but…	**Cleaner, cheaper storage in a mixed universe**	**Cheap, widespread, storable electricity changes the world**
• Battery costs fall substantially… but when including their environmental (and financial) costs, they are still higher than conventional solutions such as power grids, especially when considering low discounting financial rates on long durations including battery replacement. • Raw materials and waste are a concern. • Storage is focused on high-value use, i.e. cars and other mobility solutions. • Stationary uses remain specific and are somewhat limited to islands. Specific network issues, such as reliability, or customer segments, like solar PV with self-consumption supported by regulation, are other key use cases. • Widespread development of digital makes demand response easier.	• Storage is getting cleaner and cheaper. This includes electricity, hydrogen, and thermal storage, as well as synthetic gas and liquid gas. • Strong development in utility-scale storage such as electricity and gas. • Local district heating and cooling storage, local hydrogen and liquid storage are more widespread • On-site thermal storage and demand response through digital is widespread. • Car batteries are mostly used for demand response smart charging. Injecting back to the grid wears out the battery and remains unsustainable from a global environmental and economic point of view. • Establishment of a multi-mix decarbonated universe (power, gases, liquids). • High shares of renewable sources are enabled.	• Inexpensive electricity storage is widespread thanks to disruptive innovations such as electrical capacitance, ceramics and other disruptive materials; solutions boast a life expectancy of 12 years and are free of chemical and environmental footprints. • Power storage is everywhere. • Power supersedes gas,hydrogen, and thermal thanks to its low financial and environmental cost. • Most cars are in vehicle-to-grid mode (V2G, with injection back to the grid). • Smart digital use of appropriately sized assets for grids, storage and demand.

Capgemini's prediction for 2040:

We anticipate the first or second scenario, as the third requires significant technology disruptions.

2.2.5. Hydrogen (H_2)

Hydrogen is an energy carrier like electricity. Will hydrogen achieve progress in its end-to-end value chain in generation, transport and distribution, and local use so as to take a significant market share in terms of efficiency, cost, and low carbon content?

+	++	
H_2 for specific large-scale and mobility use	**H_2 develops in mobility and mixed gas grids**	**Pure H_2 grids**
• Electrolysis and fuel cells remain more expensive in most applications. • At the same time, hydrogen finds a partial market in chemical batteries because no single technology fits all requirements, such as the need to vary tech and raw materials sourcing. • H_2 generation is focused on physical or virtual power plants for longer running hours, mixing solar PV, wind, and marginal nuclear at night and in low seasons. • In mobility, hydrogen and fuel cells develop along with electric batteries and high-performance internal combustion engines (ICE). • Trains and long-distance haulage trucks find their hydrogen path, as do buses and urban last-mile freight logistics for air quality purposes in cities	• Fuel cells and electrolysis are cost competitive, with much higher end-to-end efficiencies, longer lifespans, improved cleanliness, and reduced/ eliminated platinum. • H_2 develops further in car mobility and in stationary uses, especially through injection into gas grids of excess renewable energy, such as large-scale power-to-gas. • Gas grids easily accommodate fluctuating hydrogen rates of 3-30 percent. Customers' smart meters, appliances and processes self-adapt to the local energy content of gas thanks to day-ahead communication of the hourly H_2 gas content by the network operators. • Regulation fosters synergies rather than competition between power and gas grids, with differentiated roles in densely populated and non-densely populated zones.	• Dedicated pure H_2 grids for industry, rail and road mobility, residential and commercial uses are made possible if both 24/7 industry uses and cheap large-scale renewable or decarbonated sources are available. • NB: In northern Europe (Germany, Netherlands, Belgium, France) and the USA, 2,500 km of pure hydrogen pipelines already existed in 2018 for petrochemical purposes, but these pipelines are based on fossil hydrogen, yet with carbon intensities above 300 gCO_2/kWh.

Capgemini's prediction for 2040:

Scenario 1 is starting. Scenario 2 may develop but there's no sign of it yet. Scenario 3 may happen locally.

2.2.6. Grid

This is a focus on the evolution of the electricity grid.

+	++	
Smart grids at scale for main operators	**Microgrids as an alternative to existing infrastructures. No new grid, depletion of existing ones**	**Smart energy flexibility everywhere**
• Decentralized and variable renewable energy sources (RES), as well as new intensive electric usages (i.e. EV charging) will trigger the development of smart grids for the distribution sector. This move to distribution of the smart grid "at scale" is enabled by the learnings from thousands of smart grid experiments, as well as evolutions in technology, including IoT, 5G real-time telecommunication, intelligent automation and transformers with embedded connectivity. • In 2020, some world-leading DSOs will launch smart grid at scale programs. Different roadmaps are expected, all with at least one or two decades of investment. We assume that the most advanced players will reach full deployment in the 2040s and 2050s, when the vast majority of grid operators will join. The magnitude of investment needed for grids with more fiber than copper will require regulation changes.	• In new or completely refurbished districts and in developing economies with energy efficient buildings and large-scale local generation or self-consumption, it can make more sense to increase the number of microgrids instead of changing and developing existing networks. • This can also work for large consumers developing their energy autonomy (campuses, large industrial plants, hospitals, etc.). • Microgrids mean local generation, storage, and software in energy-efficient buildings/plants and autonomous/self-sufficient consumers. • These new energy paradigms can make a centralized grid redundant, even depletion of some existing ones could become neither competitive nor even "insurantial".	• Huge progress in energy efficiency and full decentralization (because it's more competitive and cleaner) makes possible a big disruptive shift to a smart energy flex at any level. • 2040 is probably too early for this scenario but it could well be flourishing in limited areas.

Capgemini's predictions for 2040:

- In developed economies with dominant and large grid operators, smart grid at scale should be deployed during the two coming decades.
- Multiple consumption zones in developing economies or islands (as well as select developed regions) will be threatened by microgrids and could signal centralized infrastructure depletion.
- Possible global disruption via smart flex could occur after 2040, or even become the paradigm for newly constructed generation and consumption assets in localized areas.

2.2.7. Superconductivity

Superconductivity was discovered in 1911 by physicists in the Netherlands. They observed that below a certain critical temperature (Tc), the electric resistance in some materials drops to zero. The potential applications of this phenomenon drew massive efforts for more than a century, with Nobel prizes at each step, whether theoretical or experimental. Applications appeared wide-ranging since the absence of any resistance means no energy loss in power systems and very short time responses in electronics. Unfortunately, for 75 years Tc remained unchanged at around 20 K (-250° C). The materials being used were essentially metals and metal alloys, which are easy to transform into electricity wires. In 1986, two physicists discovered a new class of materials, which allowed the increase in Tc. This resulted in worldwide competition which brought Tc to around 100 K (-170° C).

Present developments and experiments	Future developments
• It is tempting to use superconducting cables to transport energy since there is no energy dissipation. However, the energy loss in the French grid is around 10 percent of the total energy produced, which means that around five nuclear plants only work to heat the cables. • Large-scale experimentation in recent years has looked at the feasibility of transporting large amounts of power in superconducting cables. For instance, a link of more than 500 meters was installed in the U.S. by the Long Island Power Authority (LIPA) . In this case, the superconductor was copper oxide which had to be cooled at around the same temperature as nitrogen. • Superconductors are being tested in distribution power cables. The increasing density of city populations means it is necessary to provide more power. In order to avoid civil engineering works, it is tempting to use the conduits that previously hosted the original cables. For this reason, RWE uses superconducting cables in the distribution network in downtown Essen in Germany. • Research is underway regarding how to build superconducting electricity generators. Such machines would allow more powerful generators to be installed in wind turbine nacelles without having to change the mast. • Superconductors are already used in medical devices such as MRI. • Big efforts are now devoted to building quantum computers where superconductivity is one of the favored approaches.	• Research is ongoing to find new materials that could work at higher temperatures and offer greater affordability. Superconductivity at room temperature would avoid cooling—though this borders on fantasy! • The benefits would be huge: • Savings of around 10 percent in electricity energy transportation. • Ease of distribution of electricity in very dense areas. • Smaller and lighter power generators. • Possible development of quantum computers.

Capgemini's prediction for 2040:

- It's probably too early and too expensive for superconductivity's huge potential to be scaled up.
- R&D will continue with more and more experiments and perhaps the first one or two concrete applications (in transmission or distribution lines).

[22] In the French electrical system, there are presently 2% losses in transportation, 6% in distribution and 2% in transformer stations

[3]https://www.energy.gov/sites/prod/files/oeprod/DocumentsandMedia/LIPA__5_16_08.pdf

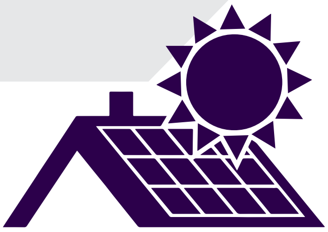
2.2.8. Mobility

The future of energy in mobility depends on advances in technology and mobility modes, as well as the ability to disrupt these two constants.

20% decarbonated mobility	50% mixed decarbonated mobility	80% carbon savings
• Fossil-fuel vehicles remain competitive through constant efficiency improvements. • E-vehicle mobility gradually gains market share through 2040, especially for short- and medium-range mobility, accounting for 20 percent of all road mileage. • Rail and inland water, the most efficient modes by one or two orders of magnitude, remain underused. • Long-range mobilities such as air and maritime continue to grow and account for more than 90 percent of fossil fuel vehicle transport. • Decarbonated agrofuels account for up to 20 percent of use in decarbonated mobility. • Mobility patterns and uses stay mostly unchanged. • Global emissions due to increased mobility continue to grow.	• Up to half of mileage is decarbonated. • Given the volumes of emitted carbon at stake, there is no one-size-fits-all solution as in the oil era with the internal combustion engine (ICE) and jets. • The full array of solutions contributes to the 50 percent achievement; electricity and hydrogen serve the short and medium range market; biofuels and power to liquids or gases for the medium and long range. • Short and medium distance mobility impacts are contained through broad development of autonomous vehicles, mobility sharing, and more convenient and flexible transport, as enabled by digital technology. • Electricity plays an important role in pure EV, hydrogen, and power to gas/liquid solutions. Digital is the key to controlling charging times for intermittent RES. • Global emissions from mobility are stabilized.	• Global relocation of industries and high carbon prices halve the volume of carbon tons/km. • Re-urbanism brings home and work closer, halving the volume of passengers/km and the time spent by individuals commuting and traveling. • As seen in the previous scenario, digital technology helps evolve short, medium and long distance travel. • Urbanism and shorter journeys enable wide usage of e-bicycles for commuting and deliveries, consuming 70 times less energy than e-cars. • Global emissions due to mobility decrease. • Only in this scenario is the decarbonation of transport in line with the Paris agreement scenario of restricting global warming to 1.5-2°.

Capgemini's prediction for 2040:

Scenario 1 is by far the most probable, with elements of scenario 2. The third scenario would constitute humans being somewhat less mobile for the first time in several thousand years. This may be quite a lifestyle change for humankind. Our ability to relocate global supply chains around the world to be closer to consumers is also not without its challenges.



2.2.9. Customer changes

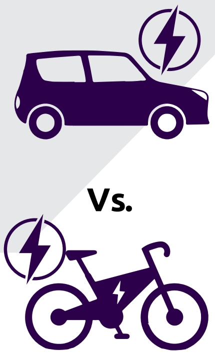
We raised three alternatives, which range from an unchanged or even possibly regressive model to an option that would imply radical change in customer practices.

+	++	+++
Still an on-tap commodity	**Decommoditization and prosuming as an individual practice**	**Prosuming as a collective and a P2P practice**
• Consumers still want energy to be on tap. • Energy remains an interchangeable, anonymous, industrial product. • Customers may or may not be interested in paying for green energy. • Utilities keep buying energy and renewable certificates as separate commodities on open markets. The origin, location, and specific methods of generation do not matter that much.	• Consumers engage personally with energy (decommoditization) when these products have meaning for them (e.g. climate change, geopolitics of energy, the need or pleasure in acting autonomously). • This can happen in affluent countries with good grids or in places with poor grids and frequent outages. Utilities are not considered to be totally reliable.	• Decommoditization takes the form of automated peer-to-peer and sharing economies applied by prosumers and small-to-large generation owners. • Personal meaning is not only in the product, but also in the relationship and the choice to join community A or B. • This can happen in wealthy countries with good grids as well as places that have no/poor infrastructure, but are equipped with microgrids and mobile payment services. • Apps automatically help prosumers manage their energy consumption through P2P and blockchain codes. Codes control energy and flexibility exchanges from prosumers and generators; i.e. stand-alone or excess generation, single owned or collective self-consumption solar PV and storage, demand response from devices. Codes set up transaction prices and manage balancing through automated balancing groups.

+	++	+++
Still an on-tap commodity	**Decommoditization and prosuming as an individual practice**	**Prosuming as a collective and a P2P practice**
• Customers may add solar panels or battery storage to their other equipment but only if needed to meet their energy demand. Becoming a prosumer is generally a result of poor grids and seen as an insurance measure. For such consumers, the best option remains power on tap (when it works). • In all cases, customers regard services and equipment from a commoditized cost and convenience point of view, i.e. "I have them because they are technically needed but I don't want to see them."		• Utilities are no longer needed for organized markets, balancing groups, or intermediating users and generators. Only asset managers for high and low voltage networks still exist. • Market design and regulations have changed. In 2040 authorities no longer license utilities. • On one hand, authorities license codes for blockchain and smart contracts, which rule energy exchanges, establish transaction prices and automate balancing. • On the other hand, authorities license new insurance bodies that replace the former trading and balancing financial provisions paid for by utilities and marketplaces. These provisions are by law decentralized inside smart contracts and automatically shared by prosumers.

Capgemini's prediction for 2040:

Customers with stable grids and healthy power supply will divide between scenarios 1 and 2. Scenario 3 is possible in a collective sharing economy but raises legal and possibly technical difficulties for fully decentralized market design.



2.2.10. New usages

Here we consider the potential emergence of new disruptive usages that can impact on our way of life and significantly increase energy consumption – or change its patterns.

–	+
Adverse new usages **Owned usages** **Heavy usages**	**Positive new usages** **Shared usages** **Lighter usages**
• Electric mobility is dominated by private ownership of vehicles with the same usage pattern as before. • No fundamental changes in household or commercial and industrial (C&I) consumption drivers. Existing drivers such as bigger, faster, cheaper, and mostly individually owned equipment/ services remain. • Electric flying cars develop, along with delivery services by electric drones and space tourism. Access to the third dimension has heavy energy and raw material costs but is largely outweighed by customer desire and consequent economic value. • Residential air conditioning and 3D printing are universal.	• Households, C&I and public authorities shift to progressive drivers such as total cost of ownership (TCO), integrated efficiency, time savings, and quality of life and work. • Remote work reduces the need for mobility. • Electric cars become mostly shared and autonomous. • Robust development of e-mobility for shared and owned lightweight vehicles (e.g. bicycles, scooters) reduces the need for single driver cars. • Less traffic means a more efficient use of space and cities become smarter, cleaner, more pleasant places. • Shared services include district heating and cooling, which is centralized and uses renewable sources, thus reducing demand on electricity grids.

Capgemini's prediction for 2040:

Disruptions in usages/technologies are difficult to predict beyond the electrification trend. Consumers and businesses usually head for bigger, faster, and better – unless efficiency, cost savings or other qualitative ego-rewarding aspects, become obvious. Disruptions in usages/technologies are difficult to predict beyond the electrification trend. Consumers and businesses usually head for bigger, faster, and better – unless efficiency, cost savings or other qualitative ego-rewarding aspects, become obvious.

2.3. Digital technologies

The “Digital Technology for Energy Companies” theme investigates the impact of data-enabled technology on the energy market. Technologies explored here include: IoT (and related communication technologies, like 5G), Cloud (and SaaS / platforming), Artificial Intelligence (AI), Robotic Process Automation (RPA) with a perspective combining AI / RPA in Intelligent Automation.

While we don’t explore the absolute imperative of cybersecurity in this report, we maintain that it is critical for both the industry and society at large.

2.3.1. IoT

IoT technologies, as enabled by 5G and other communication technologies will become mainstream by 2040. Any new component, such as a generation plant or farm, will have the potential to be connected and able to communicate.

The cost of sensors has been cut by a third over the past 15 years and will continue to drop. Meanwhile, advances in communication technologies has enabled faster, direct access to new, accurate, and meaningful data. Various interesting use cases result from IoT implementation, including:

- Smart metering
- Optimizing assets (plants, networks) operations, and maintenance
- Predictive maintenance
- Critical asset tracking
- Losses reduction
- Edge computing

These can be categorized considering two levers: 1. IoT as growth through new revenues; and 2. IoT as efficiency.

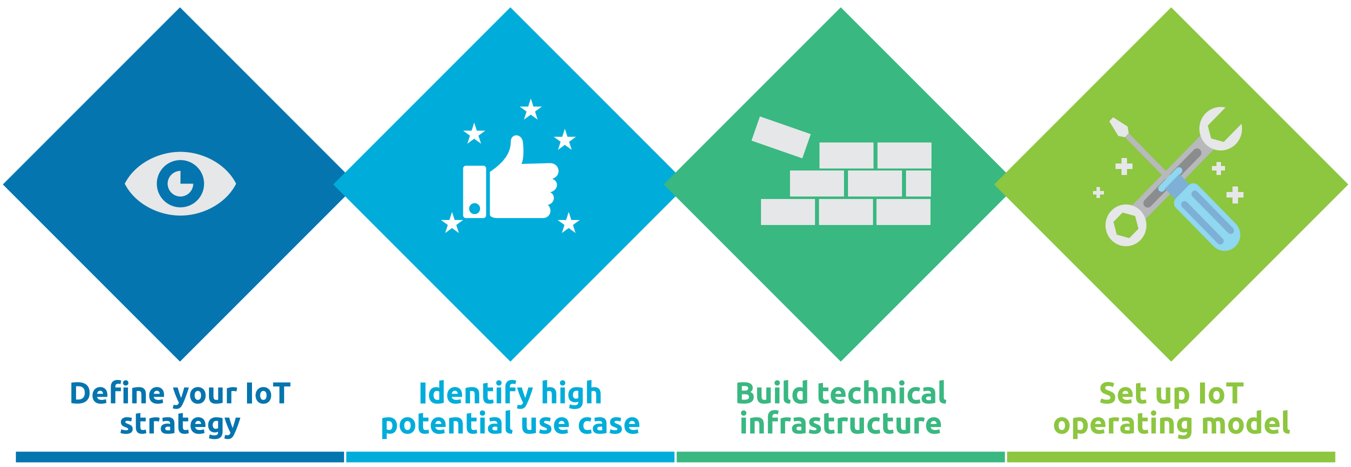
Organizations of any type should seriously consider industrialization and continuous improvement as the most difficult steps in this transformation:

Fig. *Organizations struggling to industrialize IoT use cases*

		Requirements
#ROI	**Continuous improvement**	• Business process management • End-to-end service maintenance • Data process monitoring
	Industrialization	• Clear business case • Data landscape ready to manage IoT data • Analytic capabilities to leverage IoT data • Stable regulations and standards • Cybersecurity and data privacy awareness
#Test&Learn	**Pilot**	• Identified use cases • Technological readiness
	Prototypes	• Discovering use cases • Business interests to be confirmed • Technological testing

Consider also the following successful approach:

Fig. *What are the key issues for IoT transformation?*



2.3.2. Cloud

Cloud is considered by some energy providers and utilities as a critical transformation enabler, using enhanced flexibility to adjust infrastructure to specific demand, while also making platform development easier. With cloud technology, it becomes easier to foster collaboration with ecosystems and offer new perspectives for business model development.

In contrast, some companies are reluctant because it entails major architecture transformation, which is extremely complex

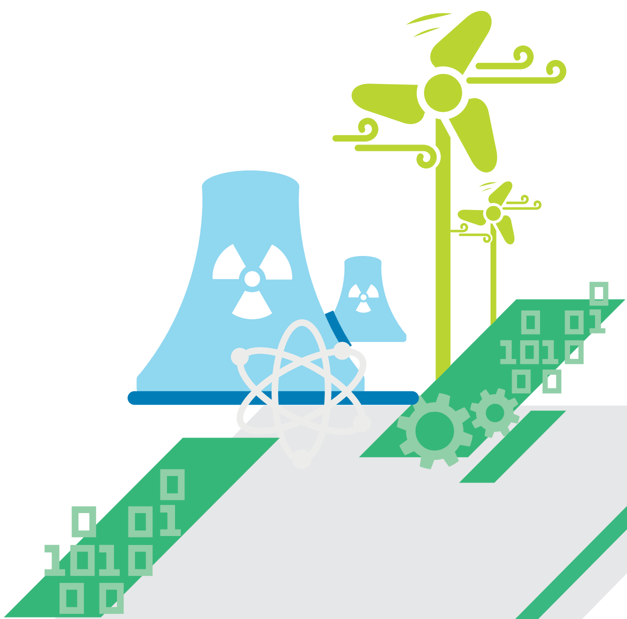
However, experts agree that cloud architecture is far more secure than any comparable technology.

Cloud will clearly play a significant role in the future of IT. The next question is if the cloud will be private, public, or a hybrid? Each enterprise will consider the question and answer it depending on the type of data and applications to be hosted.

2.3.3. AI, RPA, and IA

Capgemini's recent survey on intelligent automation (the combination of artificial intelligence and robotic process automation) clearly demonstrated that these technologies are relevant for energy and utilities players, which are more advanced in their implementation than other industries.

The advantages are likely to include:



[4] Intelligent Automation, the next digital wave for Energy & Utilities

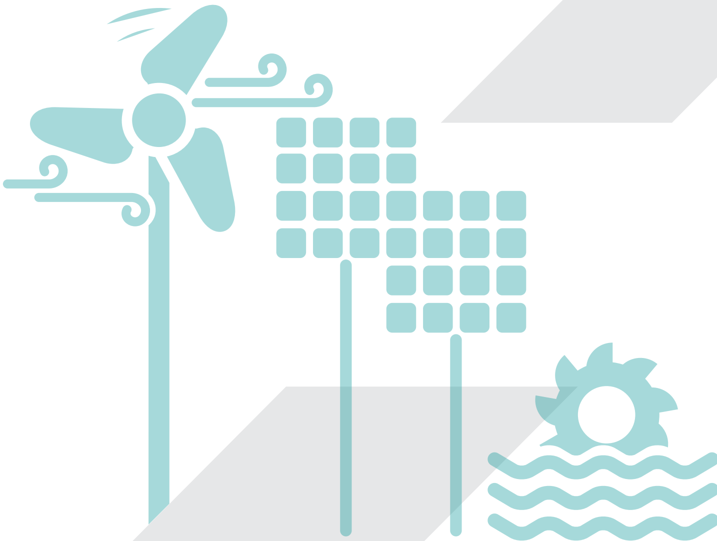
Fig. *Intelligent automation – why is it relevant for energy and utility companies?*

BOOSTING OPERATIONS	Better asset availability	Improved workforce productivity	Regulatory compliance
ENGAGING CUSTOMERS	Personalised Experiences	Reduce churn	Less number of processes
TOPLINE GROWTH	Reduce churn	Upsell/Cross sell	Faster time to market

Potential cost savings are huge:

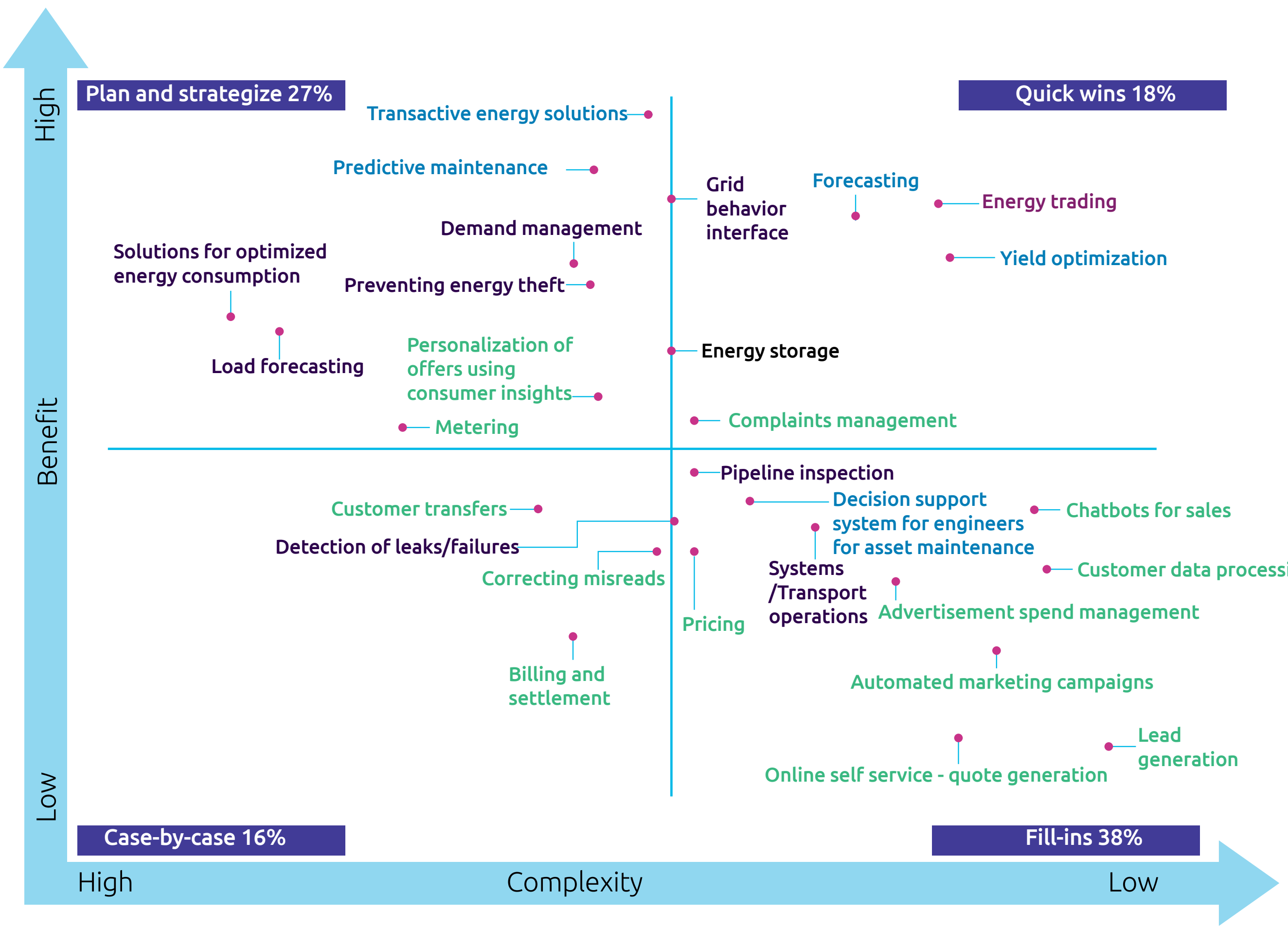
$213bn - $830bn

Cost Savings Potential through Intelligent Automation



And many core function use cases have been identified:

Fig. *Organizations are focusing on low-complexity and low-benefit use cases*



Percentage indicates implementation of use cases by energy and utilities organizations in each quadrant.

Trading | Supply/energy services/sales and marketing | Transmission/distribution | Exploration/production/generation

Undoubtedly this is the next digital wave.

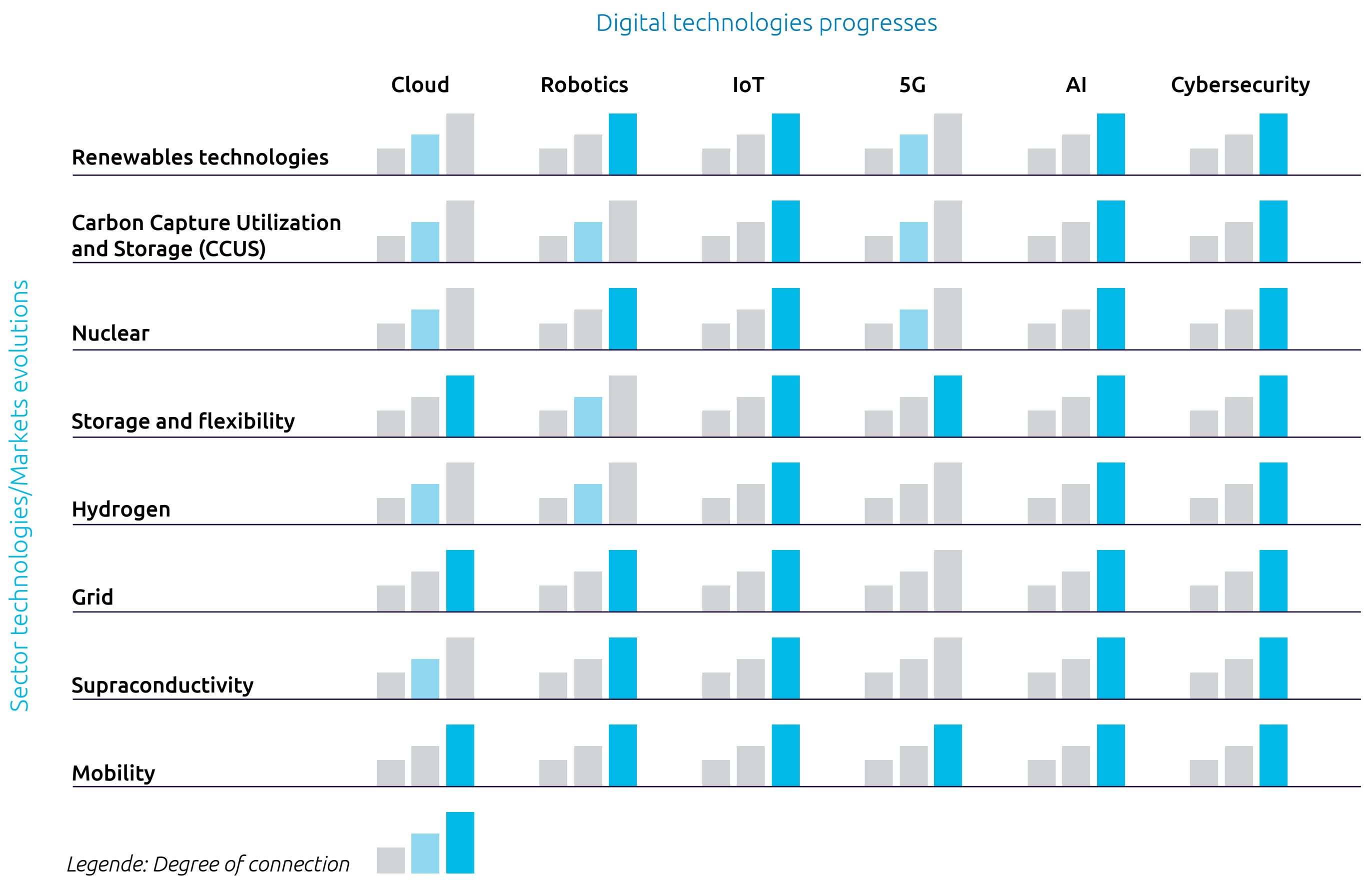
Let's consider digital technologies as key enablers of a big shift in the Energy industry.

3

An intricate techno-digital landscape supporting and provoking disruption

If insight into the future of energy reveals no major energy technology breakthrough, there will still be some major transformation within the sector. A combination of digital revolution and technology evolution will trigger these changes.

Fig. *Connection between Sector Technologies and Digital Technologies*



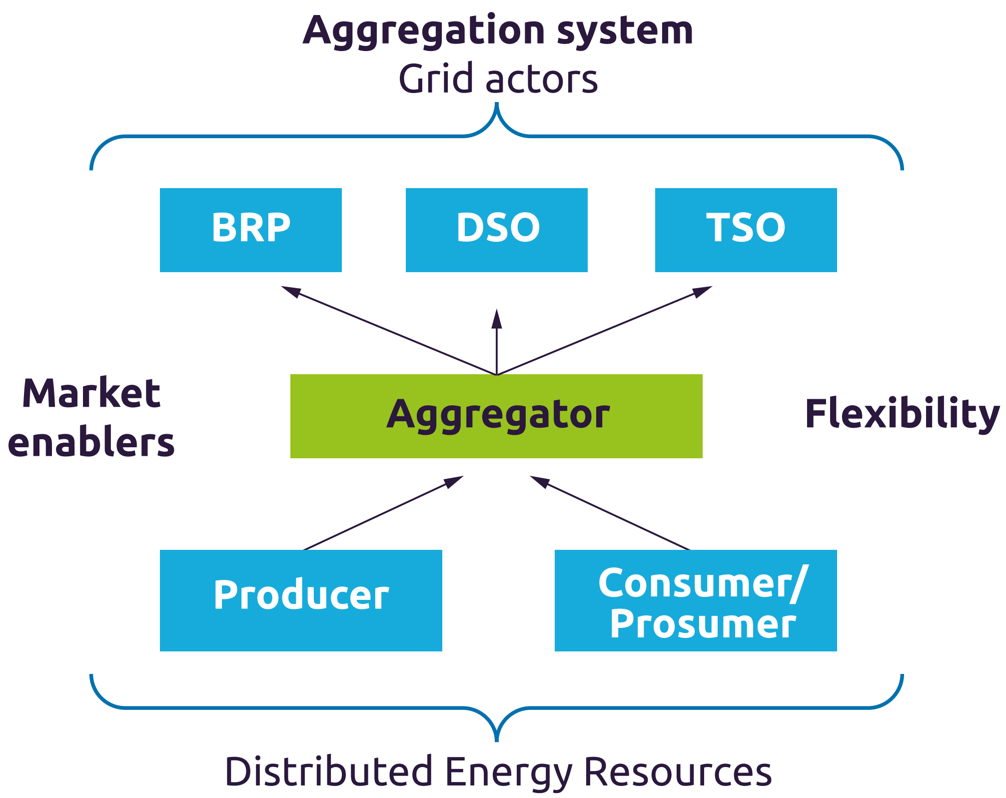
New energy models will be widely developed as a result of technology:

- combining data, assets (could be materialized or dematerialized), and infrastructure
- combining assets and infrastructure
- combining infrastructure and services
- interfacing assets, infrastructure, and services with users
- making users energy suppliers and service providers (prosumers, prosumagers),
- aggregating and optimizing massive asset portfolios.

3.1. The distributed energy world

Distributed energy – onsite or district/decentralized electricity generation and storage – will be developed and operated by a variety of small players, some connected to the grid and some not. The distribution system with its connected devices becomes a self-contained entity.

Fig. *The Aggregator Model*



Source : Dethlefs, Preisler, Renz, 2015 Capgemini analysis

The distributed energy model will become an entirely monetized services-providing system, as well as an energy aggregating and supply system.

“Prosumagers” play a key role in the distributed energy world as they contribute investments in distributed storage, usually in the form of batteries. As the number of prosumagers grows, they are no longer fully dependent on net kWh purchases from the grid. Rather, the critical service provided by the network is not energy per se, but the balancing of services, voltage and frequency support, power quality, and, most importantly, ensuring reliability.

Ultimately, most prosumagers will not cut themselves off from the grid; they will continue to rely on the network during extended periods when there is no sunshine or wind and their batteries are empty, or the oversupply collapses the centralized energy price. In this case, it will no longer be about energy, but about service reliability.

However, individual prosumagers will have limited capabilities and/or financial incentives to be careless with capturing the modest value streams of their own mini microgrids, creating a new role for aggregators.

In this world, aggregators connect producers, consumers, prosumers, and prosumagers with the grid actors, such as transportation system operators and distribution system operators (TSOs and DSOs) and balance responsible parties (BRPs). Each BRP must share information about power injection and withdrawal that comprise its balance perimeter with TSOs and, where appropriate, to DSOs. Digital technologies such as AI and machine learning modelling will help secure the system by allowing BRPs to better forecast the consumption of the consumers in their portfolios and source the required amount of energy to match that consumption.

The aggregator business is about calculating the distributed loads, generation, and storage of multitudes of consumers, prosumers, and prosumagers while remotely monitoring, controlling, and managing the portfolio of assets in real time. This allows the intermediary not only to optimize the virtual dispatching of the diverse collection of resources but also to monetize and capture their value.

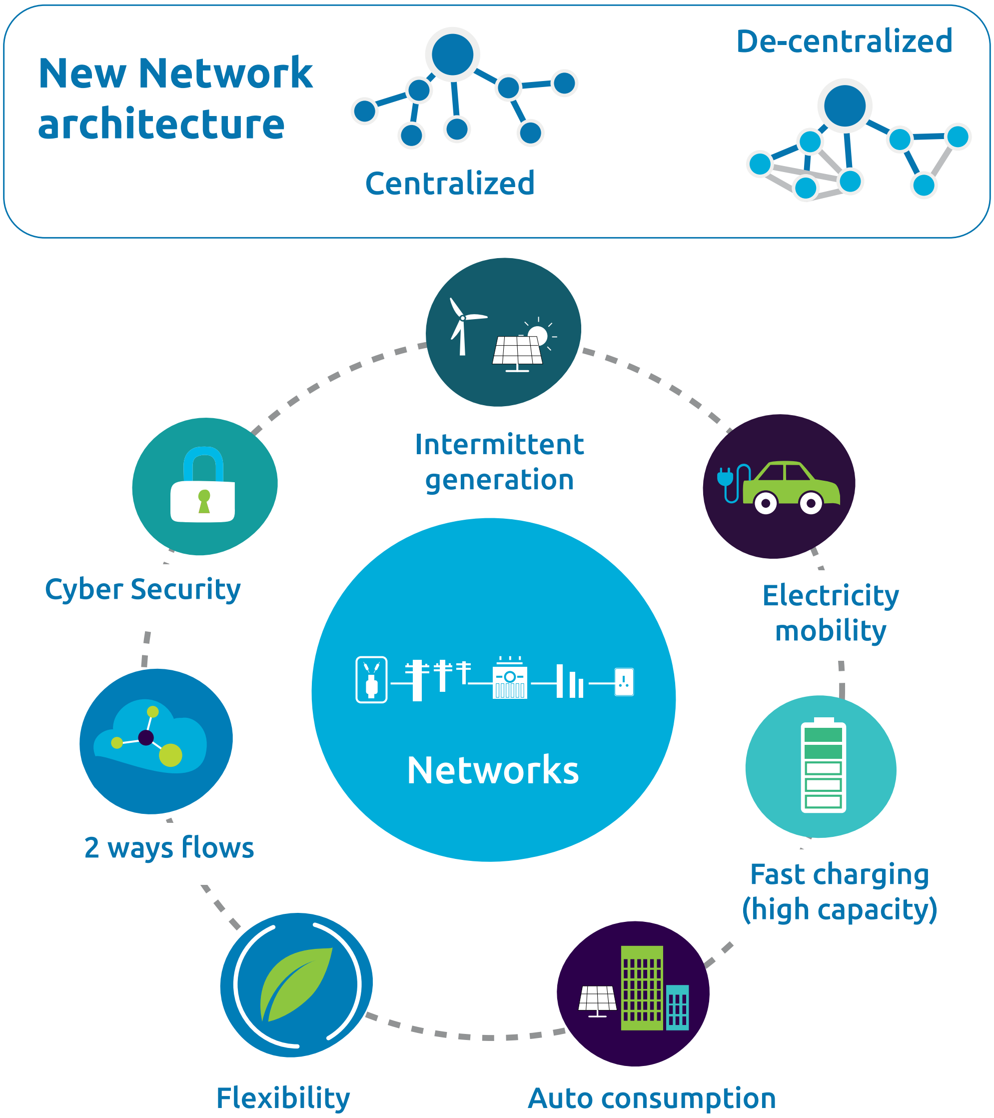
Eventually the distributed energy model will be an entirely monetized services-providing system, as well as an energy aggregating and supply system.

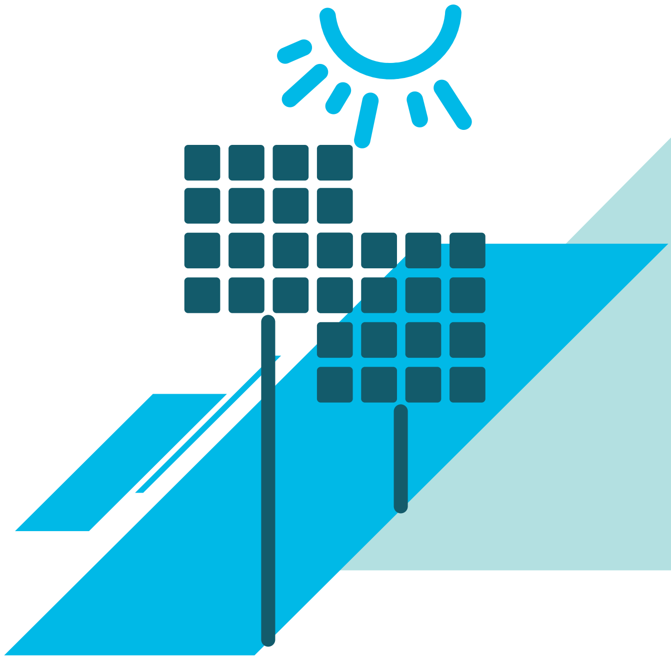
It’s easy to say this model will rely on digital technologies such as IoT, cloud, artificial intelligence, automation, realizing this vision will take considerable effort and many years of experimentation to achieve a finely tuned, efficient model.

3.2. Integrative smart grids

In a distributed energy world, grids and networks for electricity, gas, heating and cooling will face new challenges, highlighting the need for smart technology.

Fig. *The Network Model Evolution*





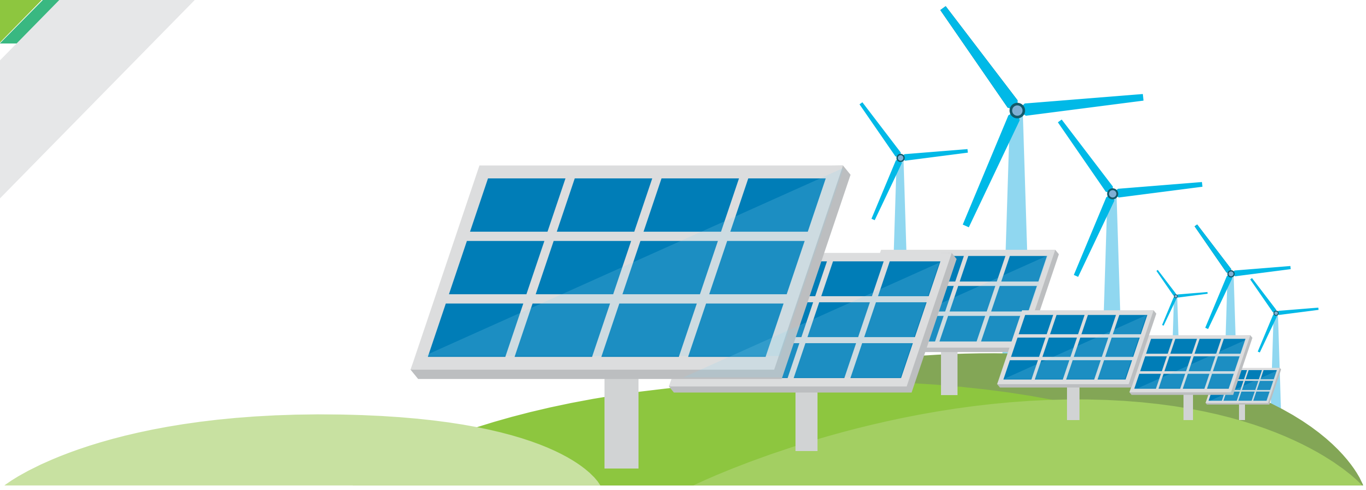
Customers also expect real-time information about outages, consumption trends, generation source and other points. They value the ability to choose their energy mix at any particular time, as well as greater resilience in terms of supply and demand.

Most of the improvements that will make the smart grid at scale possible will come from digital technologies. The table below shows a small selection of digital technologies (root digital technologies and software enhancements) and select use cases.

Digital technologies	**Enabled use cases**
IOT Data management AI Automation Cloud Drones DERMS New DMS OMS	Connected transformer Virtualized transformer lexibility, demand response Simulation, modelization Faster new connections Asset investment lifecycle planning Self-healing Real-time consumer information Scheduling intelligence Process automation Predictive maintenance Predictive vegetation management Augmented field worker Security improvement Vehicle to grid

These assets are essential to providing energy to mass populations and market actors, making cybersecurity absolutely critical.

3.3. Hybrid farms / VPP



The combination of solar and wind generation and storage is intended to bring competitive solutions for optimizing renewables intermittency as well as real-time optimization.

- Combining solar and wind production load curves flattens the combined load curve and increases dispatchable energy.
- Adding storage facilities offers the option to store energy when wholesale market prices are low and/or to provide energy to the grid (or leverage grid services like volt/var control) when prices are higher.

Hybrid farms can participate in capacity markets while operating as either virtual or real power plants. These hybrid farms include arbitrage and command control software to optimize supply in real-time.

3.4. “My energy my way”

In the coming decades digital technologies will provide many solutions that will completely change the energy customer’s journey. In the past, electricity was a black box—a characterless commodity measured manually once or twice a year.

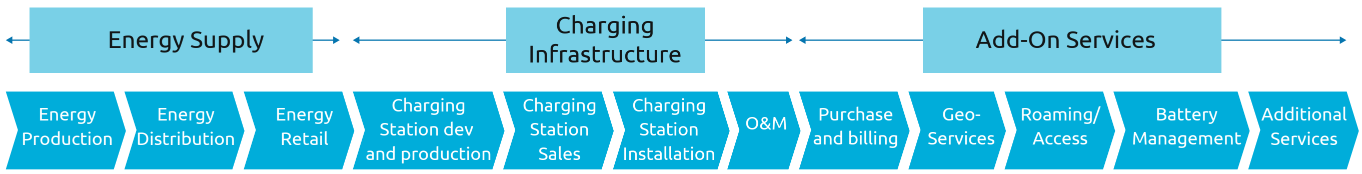
In the digital world, a consumer can choose and experience energy as they would food or clothing. “My energy my way,” represents the idea that consumers are active participants in the energy market by choosing their energy source and provider.

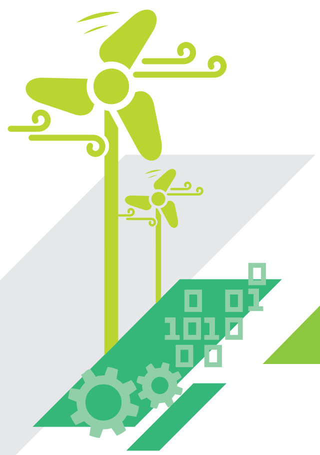
In this new landscape, a consumer can also see detailed consumption curves and pictures of the energy source. They can compare benefits and costs and easily change when something more appealing appears. In this way, electricity is totally decommoditized.

3.5. The electric vehicle/ infrastructure ecosystem

The electric vehicles ecosystem combines a wide variety of players across the energy supply, charging infrastructure and add-on services sectors. This value chain requires a wide range of technologies and/or the introduction of new services, such as vehicle-to-grid.

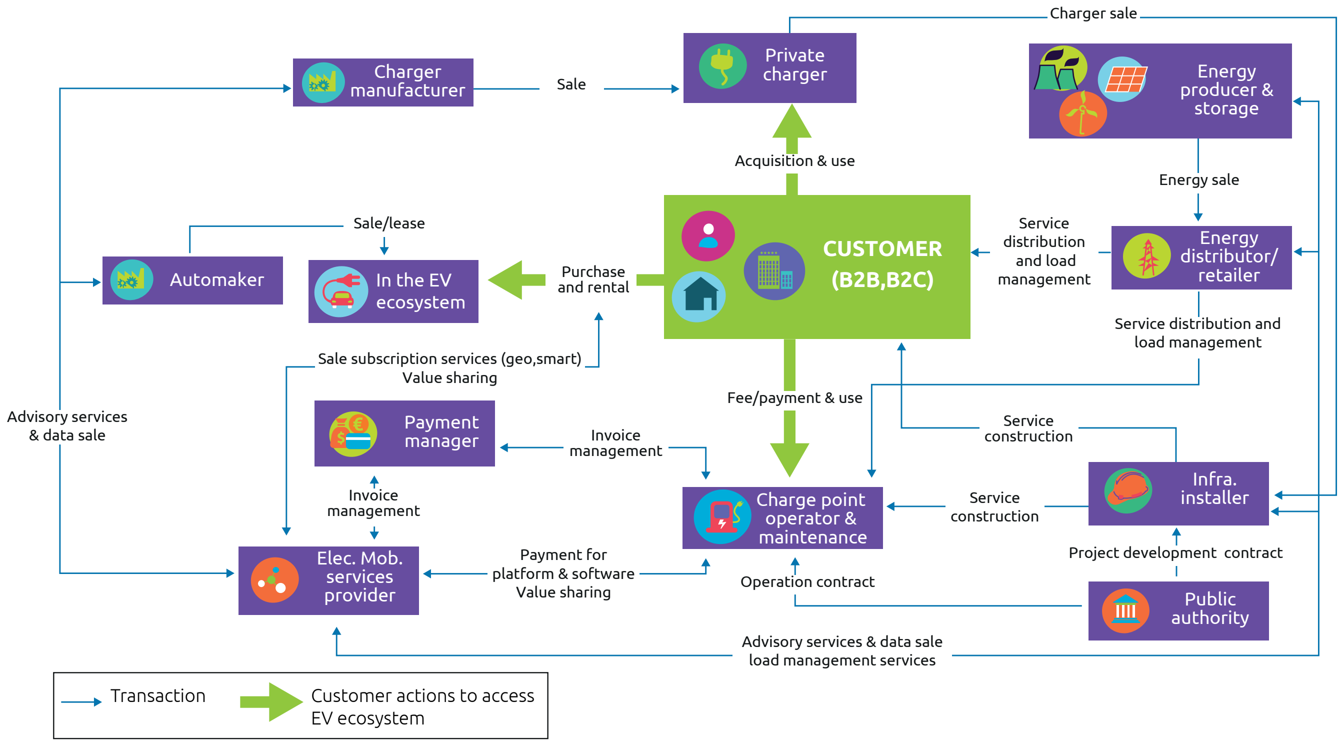
E-mobility value chain





This value chain creates an ecosystem of transactions between industrials, maintainers, energy masters, niche, and seamless e-mobility players.

Fig. *The Electric Vehicles (EV) Ecosystem*



In the ecosystem, storage units such as batteries holding excess unconsumed power will be made available for other users.

In this ecosystem, boundaries between players are totally blurred. Incumbent players like auto manufacturers, oil and gas providers, or electricity retailers have adopted the same business models and are in direct competition. On the other hand, seamless mobility providers are adopting business models involving stages across the entire value chain, combined in different fashions. In so doing, they have created entirely new value propositions and unlocked new revenue streams.

In the ecosystem, storage units such as batteries holding excess unconsumed power will be made available for other uses.

Despite a lack of clarity around the EV charging ecosystem, it is essential today to start detailing customers' needs and preferences to determine who will succeed and who will not.

For instance:

- APIs are enabling vehicle-to-grid (V2G) bidirectional charging.
- Fast battery swapping is integrated in a network of charging stations, possibly residential, and supported by technologies such as semiconductors, IoT and robotic charging.
- Communication interface relying on digitized platforms, APIs, cloud, 5-6 G, or AI to:
  - provide an overview of the network via apps by processing multiple data (i.e. sensors, visual satellite/GPS-type data feeding machine learning systems),
  - monetize the network (and support transactions), and
  - allow integration with any third-party system.

Conclusion

While the details of our energy future are far from certain, the world can rest assured that by 2040, the energy landscape will be markedly different than it is today.

As part of the transformation process, the lines between data-enabled services and energy assets such as equipment and infrastructure will continue to blur—ultimately resulting in a shift to an "as a service" business model. Along the same lines, energy will no longer be viewed as a commodity as it often is today. Rather, it will be defined by its final use—whether that is in terms of mobility, heating, charging or any other application, even the most small-sized ones or the mundane ones . Most likely, these uses will be labeled or certified according to their environmental impact (e.g. green,clean, carbon-free, recyclable, zero impact, human friendly, unconnected, auto-charged, and so on.. .).

Capgemini encourages all players, from the most established service providers to the latest tech startups, to consider these market evolutions and work to position themselves as market leaders within their value-chain domains. It is our belief that by identifying and implementing the most promising combination of deep and digital technologies, every organization can help usher in a cleaner, more efficient, more progressive New Energy era.

Recommended reading

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- Succeeding in a World Where the Future of Energy Disrupts Everything, Gartner, Analyst(s): Rich McAvey, Zarko Sumic, Ethan Cohen, Michael Ramsey, Bettina Tratz-Ryan, Keith Harrison, Stephen Smith, Chet Geschickter, Nicole Foust, Simon Cushing, Lloyd Jones, 2019
- History, Definition, and Status of V2G, Lance Noel, 2019
- Hawaii Clean Energy Initiative, Shaping Energy Policy: 2008-2019 Legislative Measures *http://www.hawaiicleanenergyinitiative.org/ , snapshot 2019*
- California Renewable Energy Overview and Programs, *https://www.energy.ca.gov/, snapshot 2019*
- Alabama Department of Economic and Community Affairs, *http://adeca.alabama.gov/Divisions/energy/Pages/default.aspx , snapshot 2019*
- The 5th ASEAN Energy Outlook (AEO5), prepared by the ASEAN Centre for Energy (ACE), *http://www.aseanenergy.org/events/past-events/ace-launches-the-5th-asean-energy-outlook-in-35th-amem/, snapshot 2019*
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- BP Energy Outlook 2019 edition, 2019
- “World Energy Outlook”, IEA, 2018 & 2019
- “Renewables Energy Statistics”, Irena, 2018 & 2019
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About Capgemini

A global leader in consulting, technology services and digital transformation, Capgemini is at the forefront of innovation to address the entire breadth of clients' opportunities in the evolving world of cloud, digital and platforms. Building on its strong 50-year heritage and deep industry-specific expertise, Capgemini enables organizations to realize their business ambitions through an array of services from strategy to operations. Capgemini is driven by the conviction that the business value of technology comes from and through people. It is a multicultural company of over 200,000 team members in more than 40 countries. The Group reported 2018 global revenues of EUR 13.2 billion.

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