IEA Roadmap targets

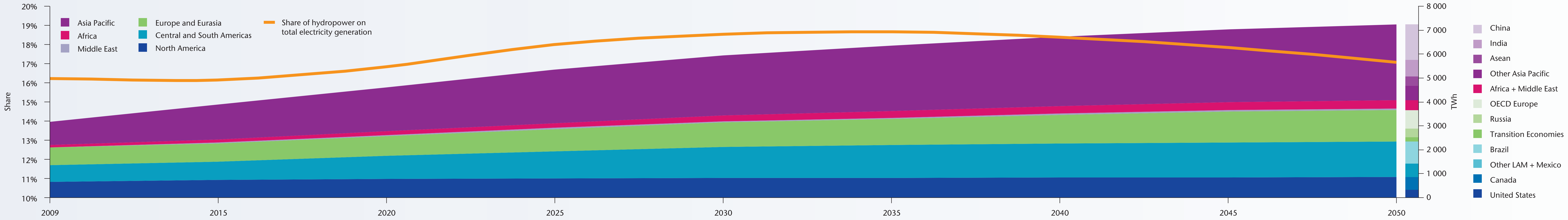
2012 2015 2020 2025 2030 2035 2040 2045 2050

International Energy Agency | Ministério de Minas e Energia | Governo Federal Brasil — País rico é país sem pobreza

Key findings

- Hydroelectricity presents several advantages over most other sources of electrical power, including a high level of reliability, proven technology, high efficiency, very low operating and maintenance costs, flexibility and large storage capacity.
- Hydropower is the major renewable electricity generation technology worldwide and will remain so for a long time. Since 2005, new capacity additions in hydropower have generated more electricity than all other renewables combined.
- The potential for additional hydropower remains considerable, especially in Africa, Asia and Latin America. This roadmap foresees, by 2050, a doubling of global capacity up to almost 2 000 GW and of global electricity generation over 7 000 TWh. Pumped storage hydropower capacities would be multiplied by a factor of 3 to 5.
- Most of the growth in hydroelectricity generation will come from large projects in emerging economies and developing countries. In these countries, large and small hydropower projects can improve access to modern energy services and alleviate poverty, and foster social and economic development, especially for local communities. In industrialised countries, upgrading or redevelopment of existing plants can deliver additional benefits.
- Hydropower reservoirs can also regulate water flows for freshwater supply, flood control, irrigation, navigation services and recreation. Regulation of water flow may be important to climate change adaptation.
- Both reservoir and pumped storage hydropower are flexible sources of electricity that can help system operators handle the variability of other renewable energy such as wind power and photovoltaic electricity.
- In order to achieve its considerable potential for increasing energy security while reducing reliance on electricity from fossil fuels, hydropower must overcome barriers relative to policy, environment, public acceptance, market design and financial challenges.
- Large or small, associated with a reservoir or run-of-river, hydropower projects must be designed and operated to mitigate or compensate impacts on the environment and local populations. The hydropower industry has developed a variety of tools, guidelines and protocols to help developers and operators address the environmental and social issues in a satisfactory manner.
- New turbines and design make modern hydropower plants more sustainable and environmentally friendly; better management helps avoid damage to downstream ecosystems.
- Hydropower projects require very substantial up-front investment, which can range up to tens of billion USD. Although hydropower is the least-cost renewable electricity technology and is usually competitive with all alternatives, financing remains a key issue. This roadmap calls for innovative financing schemes and market design reforms to ensure adequate long-term revenue flows and alleviate risks for investors.

Roadmap vision hydropower generation by region



Roadmap milestones

2012 2015 2020 2025 2030 2035 2040 2045 2050

Policy Framework

- Establish or update national hydropower inventories, at river basin level where appropriate (2012–2020)
- Update and adjust hydropower targets (2020–2050)
- Set targets for hydropower development, including upgrade and redevelopment of old HPP and additions to existing dams and waterways (2012–2020)
- Consider increasing electric capacities of existing reservoir HPP and PSP to better enable the development of variable renewables (2020–2050)
- Streamline permit processes while maintaining the highest level of sustainability requirements (2012–2020)
- Develop international co-ordination of hydropower development when river basin cross borders (2012–2020)

Sustainability and public acceptance

- Consider sustainability criteria at river basin level (2012–2020)
- Maximise sustainability benefits through co-ordination of operations of hydropower plants (2012–2020)
- Document approaches to sustainability, including protocols or guidelines (2012–2020)
- Mitigate or compensate negative socio-economic and environmental impacts (2012–2030)
- Consider positive impacts of HPP development (2012–2030)
- Develop tools to monitor and manage GHG emissions from reservoir HPP (2012–2050)

Financing

- Reform electricity markets to ensure adequate long-term revenue flows (2012–2020)
- Reconsider grid fees for PSP in pumping mode (2012–2020)
- Value ancillary services, flexible capacities and non-energy services from HPP development (2012–2030)
- Develop new risk-mitigating public financial instruments, especially for developing countries (2012–2050)

Technology

- Develop roller-compacted concrete (RCC) dams (2012–2030)
- Develop low-head and kinetic flow turbines for use in canals, pipes and rivers (2012–2030)
- Further improve turbine efficiency and environmental performance (2012–2050)
- Upgrade or redevelop old plants to increase efficiency and environmental performance (2012–2050)

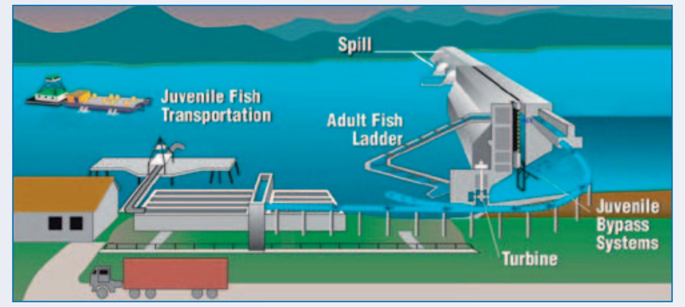
Key actions in the next ten years

- Concerted action by all stakeholders is critical to realise the vision laid out in this roadmap. In order to stimulate investment on the scale necessary to achieve the aimed-for levels of sustainable hydropower, governments must take the lead in creating a favourable climate for industry investment. Actions necessary to achieve these targets relate to the policy and market framework, sustainability and public acceptance, financial challenges and further technology development.
- With respect to policy, governments should:
  - Establish or update an inventory of hydropower potential, at river-basin level where appropriate; include options for upgrading or redeveloping existing plants to increase performance; assess feasibility of adding hydropower units to dams originally developed for flood control, irrigation, navigation or drinking.
  - Prepare hydropower development plans with targets; and track progress towards meeting those targets. Least-developed countries could receive appropriate support to this end.
  - Develop and promote a policy framework and market design for appropriate and sustainable hydropower projects.
- With respect to sustainability and public acceptance, governments and relevant stakeholders should:
  - ensure that developers and operators document the approach to sustainability that will be followed, such as environmental impact assessment reports and/or voluntary protocols;
  - disseminate information to public and stakeholders on hydropower's role in producing sustainable energy and contributing to targets for climate change reduction;
  - consider sustainability issues in the co-ordinated operation of hydropower plants at electrical-interconnected river-basin level to take advantage of hydrological complementarities.
- With respect to financial challenges, governments and relevant stakeholders should:
  - include the financing of hydropower on governments' policy agendas and develop new public risk-mitigating financing instruments;
  - develop effective financial models to support large numbers of hydropower projects in developing regions;
  - provide guidance to determine the real value of hydropower and pumped storage, and mechanisms for remuneration;
  - establish economic tools to assess the non-energy contributions of multi-purpose hydropower developments.
- With respect to technology development, governments and industry should:
  - expand, co-ordinate and disseminate results of technology development to improve operational performance and reduce costs of development;
  - ensure that the industry develops technologies at hydropower plants to better support the grid integration of large amounts of variable renewable energy.

Sustainability

Considerable efforts have been devoted by the hydropower industry and expert networks such as the IEA Hydropower programme to elaborate guidelines and briefings on the interactions between hydropower and the environment.

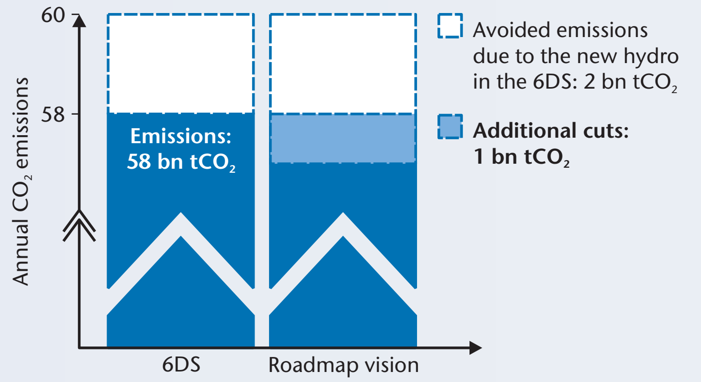
Mitigating the impacts of hydropower deployment on wildlife requires sound technology choices, such as fish-friendly turbines, and specific equipment to facilitate fish migration up and down streams. After plant building, continuous care while operating the plants allows to further reduce impacts.



Morever, the "Platform HPP" concept currently in development in Brazil aims to limit the impacts of construction in areas with no or low anthropogenic activity. Inspired by the functioning of offshore platforms for oil and gas, it helps prevent the development of nearby permanent settlements for workers and families and aims to become an enabler of permanent environmental conservation.

CO_2 emission reductions

Contribution to annual CO_2 emission reductions by 2050 due to newly-built hydropower plants



Additional hydropower in the laissez-faire scenario (6DS) of IEA *Energy Technology Perspectives 2012* will save 2 bn tCO_2 emissions per year by 2050, assuming they replace a mix of fossil fuel plants.

Further additions to hydropower as developed under this roadmap vision would save another 1 bn tCO_2.

Newly-built hydropower plants could thus save up to 3 bn tCO_2 per year in the middle of the century.

Economics

The bulk of the cost of electricity from hydropower plants derives from the investment cost. While electric equipment has similar costs per MW in all countries, civil works are very site-specific. Lower investment costs are seen in regions where the hydropower potential is mostly untapped, such as Africa, Asia, and Central and South America. In more industrialised areas, where around half the technical potential has already been tapped, remaining possible sites are more difficult or distant, and labour costs are higher, making new projects costlier.

Overall investment cost ranges

USD/kW	Large projects	Small projects	Upgrades	PSP
Minimum	1 050	1 300	500	500
Maximum	7 650	8 000	1 000	2 000

The levelised cost of electricity (LCOE) from HPP derives from their investment costs but not only. It is very sensitive to variations of the cost of capital used for financing, and of plant capacity factor (full load hours). Capacity factor rests on water inflows and reservoir capacity, but also on the ratio of these inflows over the electrical capacity of the plant, that is, the role the plant was designed to play in the electric system – providing base load, mid-merit, or peak electricity.

The first table below shows variations of the LCOE for a development with a construction period of 5 years followed by a 50-year life span. The investment cost is assumed as USD 1 500/kW with operation and maintenance (O&M) costs of 2.5% of this amount. In this example, the capacity factors vary with the sites, *i.e.* correspond to different water inflows, and different electricity outputs (in kWh).

Variations of the LCOE of HPP with WACC and load factor (different water inflows, same electric capacity)

LCOE (USD/MWh)		Weighted Average Capital Cost or Discount Rate		
		8%	10%	12%
Capacity factor	25%	90	110	133
	50%	41	51	61
	75%	28	34	41

Note: A capacity factor of, *e.g.*, 50% means 4 380 hours per year at full load.

In the second example below, the water inflow does not change. The output (in kWh) is thus constant. The different load factors correspond to different capacities. Investment costs vary with the power of turbines and alternators.

Variations of the LCOE of HPP with WACC and load factor (same water inflow, different electrical capacities)

LCOE (USD/MWh)				Weighted Average Capital Cost or Discount Rate		
		Main role	Investment costs	8%	10%	12%
Capacity factor	25%	Peak	USD 1 750/kW	47	59	71
	50%	Mid-merit	USD 1 500/kW	41	51	61
	75%	Base load	USD 1 250/kW	35	43	51

Services and flexibility

The first service hydropower provides is clean, inexhaustible electricity. In emerging economies and developing countries, it can improve access to modern energy services and alleviate poverty, and foster social and economic development.

Reservoir and, to a lesser extent, run-of-river hydropower plants with pondage capacity also provide flexibility services to electric grid operators, especially when confronted with the deployment of variable renewables such as wind power and solar PV. These services include:

- back-up and reserve with quick start and shutdown capabilities;
- spinning reserve;
- black start capability;
- regulation and frequency response;
- reactive power compensation and voltage support.

One way to increase the ability of hydropower to help manage variable renewables is to repower turbines and alternators, increasing capacities (MW) for constant output (in kWh). Another is pump-storage hydropower, which will be particularly useful in countries with large-scale penetration of variable renewables such as wind and solar PV, and limited sources of flexible supply including hydro. This roadmap forecasts that global capacities would grow from 140 GW today to 400 to 700 GW in 2050, as shown on the table below.

Expected PSP capacities in 2050

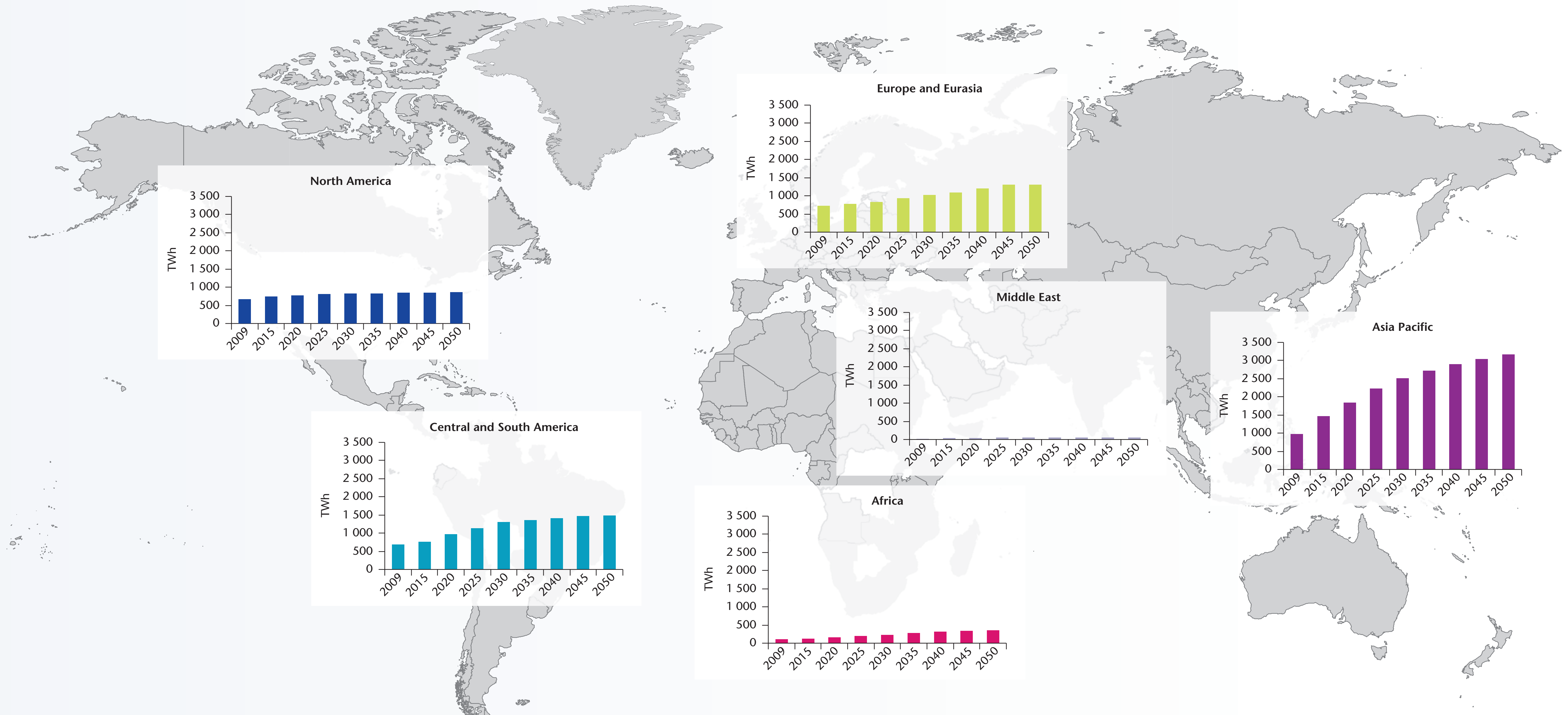
		China	United States	Europe	Japan	Rest of world	Total
Low estimate (2DS)	VRE % total energy	21%	24%	43%	18%		
	Hydro % total energy	14%	6%	13%	12%		
	PSP/total capacity	4%	4%	6%	11%	2%	
	GW	119	58	91	35	109	412
High estimate (Hi-REN)	VRE % total energy	34%	37%	48%	33%		
	Hydro % total energy	15%	6%	11%	13%		
	PSP/total capacity	5%	8%	10%	12%	3%	
	GW	179	139	188	39	164	700

Note: For both low and high estimates, the first two lines indicate the percentage of variable renewable energy, and of hydroelectricity, relative to total energy in the electricity mix, as resulting from the 2DS or the Hi-REN modelling; building on this information as explained in the main text, the third line shows this roadmap's assumption of the possible share of pump-storage capacities over total electric capacities. The fourth line expresses these results in GW.

ROADMAP INSIGHTS

Hydropower

Regional hydropower generation



This map is without prejudice to the status of or sovereignty over any territory to the delimitation of international frontiers and boundaries and to the name of any territory city or area.

International Energy Agency
Ministério de Minas e Energia
GOVERNO FEDERAL BRASIL PAÍS RICO É PAÍS SEM POBREZA