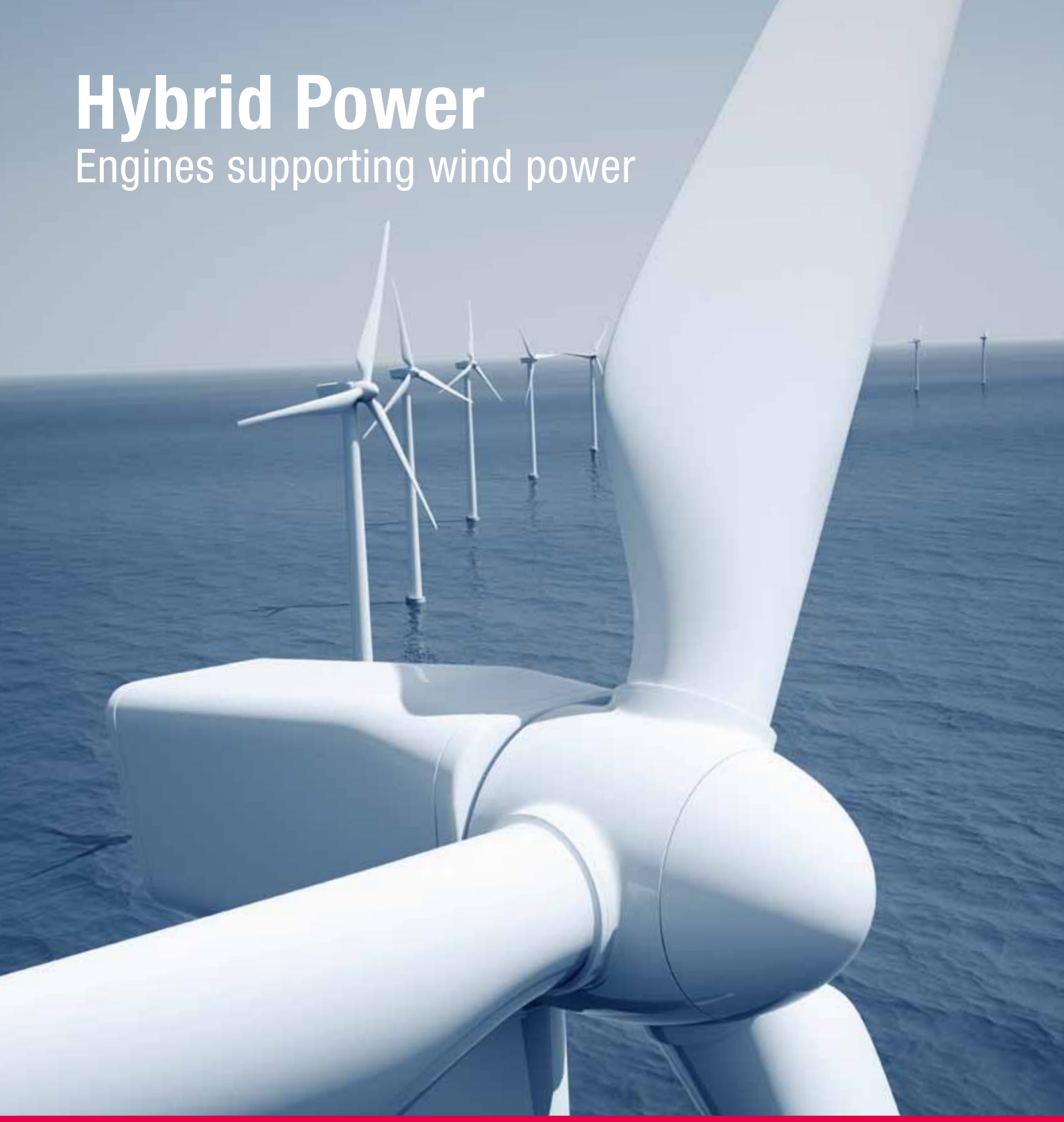
Hybrid Power

Engines supporting wind power



Engineering the Future – since 1758.

MAN Diesel & Turbo

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– since 1758.

MAN Diesel & Turbo is one of the world's leading suppliers of land-based and floating power plants based on large diesel and gas engines. Over the last century we have built thousands of diesel power plants worldwide. The experience we have gained and the technology we have developed over that time enables our specialists to tailor power plants to the individual needs of customers all over the world.

During this long history the companies within the MAN Group have always been world leaders in their fields, both in design engineering and the commercial application of new technologies and, more recently, the innovative integration of mechanical engineering with state-of-the-art electronics.

More than ever before, MAN Diesel & Turbo's development focus is on the environmental performance of our engines. Using our unrivalled grasp of large engine technology, we aim to make our engines progressively cleaner, more powerful and more efficient.

With our absolute commitment to reducing emissions while increasing fuel efficiency and power density and, with our active partnership in the emissions law making process, we intend to be part of the global emissions solution.

Why Engines?

Hybrid power

Wind represents an attractive source of renewable energy – it's free, widely available and produces no greenhouse gases. However, there is one serious drawback: it is very unpredictable.

The answer: hybrid power

Whichever way the wind blows, though, you can rely on a hybrid power plant. By combining wind turbines with fast, high efficient gas or diesel engines, these plants ensure a continuous power output, while keeping fuel costs and CO_2 emissions down. That helps keep the plant sustainable and eligible for subsidies or selling carbon credits.

Further benefits

To maximize your independency and flexibility in operating, there is the option of running your engines on a wide range of various fuels like oil based derivates, gaseous fuels, liquid bio fuels or complete dual-fuel systems. Combined with this operating flexibility and the use of the highest efficient prime mover technology the MAN hybrid solution sets the benchmark in the lowest possible life cycle costs and environmental footprint.

Changes in Energy Thinking

Changes in worldwide energy and environmental policy and their influence on national power systems

The Copenhagen target to limit global warming to an increase of 2 degrees Celsius together with national targets to reduce CO_2 emissions resulting from the advice of the Intergovernmental Panel on Climate Change (IPCC) will lead to a fundamental change in many power systems worldwide. In the last 40 years many countries have developed energy systems for meeting demand for base, mid and peak load, commonly using nuclear, coal, gas oil-fired and hydro electric power plants. Worldwide electricity production was responsible for 33% of total global fossil fuel use in 2006 and 38% of fuel combustion-related CO_2 emissions.

Electricity markets

To understand electricity market mechanisms and the link to the generating installations and their influence on technology orders, we would like to use the German market model as an example. The merit-order instrument, first introduced in Great Britain (GB) and today replaced in GB by a more complex bidding system, is the price building instrument in Germany and regulated via the European Energy Exchange (EEX) in Leipzig. Approximately 10 - 30% of the

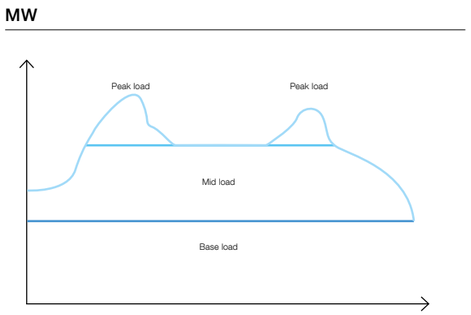


Figure 1: Typical daily electricity demand curve with base, mid and peak load.

Changes in Worldwide Energy

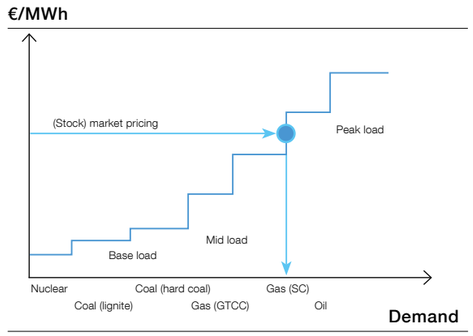


Figure 2: Merit-order curve in an all-available electricity mix.

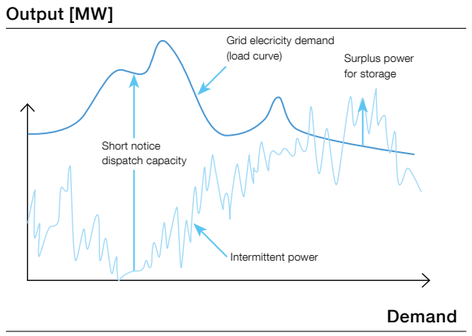


Figure 3: Load curve with a high share if intermittent power.

electricity generated in Germany is traded via this market instrument. The remaining percentage of power is directly produced under electricity supply agreements e.g. for industrial and larger captive customers.

The operating order of power plant installations in many countries is mainly based on the substitution effect, which means that the “last virtual power plant” in the order of sequence sets the price in variable costs.

To get an idea of this instrument we can say metaphorically that the generating technologies “are called according to merit-order”. Weighted to scientific precision, we can explain the merit-order curve also as a step function which includes every power plant installation which is available for operation described by the power output in MW and the price for the electricity generation in €/MWh.

In daily practice this merit-order curve starts with a price signal from the electricity exchange with the lowest power plant in case of the variable costs which is, in an all available technology system, very often a nuclear power plant. The last nuclear power plant in this order sets the price for the next technology- here it could be a coal-fired plant with next lower variable costs. The last power plant in this order is the power plant technology with the highest (variable) electricity generating costs in the power system.

The aim of the merit-order system is to have an efficient instrument to rank available electricity generation sources in a power system in the order of their electricity production costs so that the most efficient technology is called to generate, instead of a less efficient, high price power plant.
1 Variable costs = Costs for operation & maintenance of a power plant (€/MWh) + fuel costs (€/MWh) - excluding capital costs for new installations.

Fundamental challenges for power systems

The environmental policy of many countries worldwide generally calls for a higher share of renewable energy sources in their power generation concepts to reduce emissions and the high share of fossils in the electricity generation mix. In the European Union for example, the target is set to 20% for renewable energy sources by 2020.

Renewable power generation installations generally have the following characteristics:

- Fluctuating feed-in with a limited predictability as a result of weather-related variations.
- Very often a geographical concentration on coastal and/or remote areas.

To meet the future model of supply and demand in a power system with a higher share of fluctuating capacities and at the same time ensure grid-stability with regard to frequency and voltage control on a scale of seconds to several minutes, the available power generating mix of a power system has to be changed to include more flexible installations with good performance in costs, emissions, efficiency and grid servicing.

Denmark is an impressive example of how emissions increase if installations with a fluctuating power output (mainly wind power) are counter-balanced by inflexible installations such as coal-fired power plants running under part-load.

Denmark is the world’s most wind energy intensive country with more than 6,000 wind turbines generating 19% of its electricity. Being highly intermittent in its output, wind power has recently (2006) met as little as 5% of Denmark’s annual electricity consumption with an average of 9.7% over the last five years.

Not one conventional power plant has been closed in the period that Danish wind farms have been developed.

In fact, the Danish grid used 50% more coal-generated electricity in 2006 than in 2005 to cover wind energy’s failings. Fast ramping-up and down of those plants has increased their pollution and carbon dioxide output – carbon emissions rose by 36% in 2006 compared to 2005.

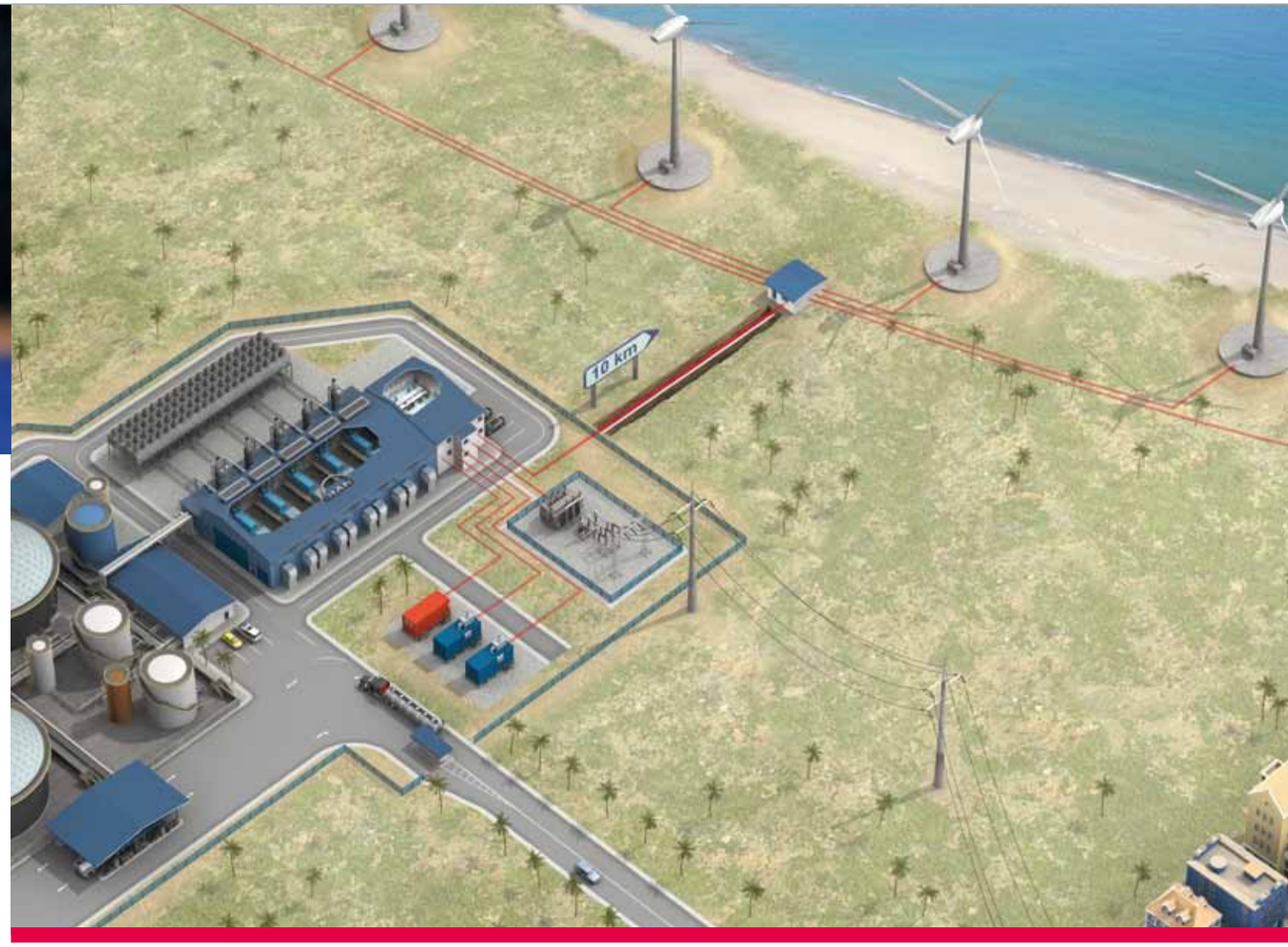
Wind Diesel Hybrid

A sustainable solution

The last years wind energy has been worldwide the most dynamically growing energy source. One of the main barriers to increase the wind energy penetration relies on the fact that it is an intermittent power supply which affects the grid´s stability. Wind Diesel Hybrid technology use wind energy as the primary source of electricity generation and diesel engines as support during calm periods, tropical storms or peaks in demand.

MAN Diesel & Turbo engines have the advantage that they require only a very short start-up time and therefore are available virtually at the press of a button. The very fast ramp up response enables them to kick in quickly to ensure a constant and reliable supply of power to the consumers. The extremely high efficiency of diesel engines also ensures the maximum possible yield from the fuel used.

On the other hand, if Bio-fuels are used to run the highly fuel flexible MAN Diesel & Turbo engines the result will be a 100% CO_2 neutral Wind Diesel Hybrid System.



Graphic by hokolo 3D

Engines that are...

MAN gas, dual-fuel or diesel engines are the perfect match for wind power: efficient, reliable, fast and flexible. They make wind power a viable option for continuous energy supply.

Efficient

Even when operating at the low loads often associated with hybrid power plants, our engines are highly efficient. In other words, they deliver energy with lower fuel costs and lower emissions.

Reliable

A back-up source of energy shouldn't need a back up. MAN engines are famously robust. They require little maintenance, even with the fluctuating requirements of hybrid plants. That translates into less frustrating, unproductive downtime for you.

Fast

Another key advantage of MAN engines is that they can be brought on stream in just seven minutes. Meeting peak power demand or counteracting a sudden drop in wind is as simple as pressing a button.

Flexible

A MAN engine won't make you dependent on expensive or unreliable fuel supplies. Practically all MAN Diesel & Turbo engines can be efficiently operated with a wide range of biofuels, from palm oil to animal fat, without the need for significant modifications. For even more flexibility, MAN Diesel & Turbo offers gas and dual-fuel engines that will run on gas or diesel.

So you can keep your plant running under almost any circumstances. If one kind of fuel becomes difficult to obtain, or prices move beyond your reach, you can simply switch to another. Or you can start running your plant on conventional diesel fuel, and move to new biofuels as they become available – a real option given the rapid pace of development in this field (and one in which MAN is at the forefront).

And of course, your plant will become even better for the environment.

See our brochures on Green Power and Gas Engines for more specific information on these products.

Winds Create the Right Energy

Reference Bonaire

MAN Diesel & Turbo, in collaboration with wind turbine manufacturer Enercon and planning and consulting firm Econcern, built in 2009 the world's largest Wind Diesel Hybrid power plant on the Caribbean island of Bonaire. The wind park will be the primary source of electricity generation. During calm periods, tropical storms or peaks in demand, the engines in the diesel power plant will also kick in quickly to ensure a constant and reliable supply of power to the population.

The planner´s target is to become the first CO_2 neutral Island with:

- 12 Wind Turbines, each 900 KW
- 5 Diesel Engines, each 2,5 MW to be operated on biofuel (first imported certified vegetable oil, later self produced algae oil)

For emergency purposes a 3 MW battery system and emergency diesel generating sets were also installed. Communication between the diesel engine-based generating sets and the wind farm is via a so-called power management system. Grid stability, which is of fundamental importance to the island, will be secured by the lead of the diesel engine power plant. The extremely high efficiency of diesel engines also ensures the maximum possible yield from the fuel used. This – according to the plans – will be switched over within the next three years entirely to bio-fuel, which is to be obtained from algae. The Wind Diesel Hybrid power plant will then sustainably provide the entire island with CO_2-neutral electricity and thus save around 70,000 tonnes of the greenhouse gas a year compared to the current power plant, which runs on fossil fuels.

The Wind Diesel Hybrid power plant is not funded by the state, but instead is being built exclusively on the basis of economic considerations. The result is a very environmentally friendly and autonomous supply of energy to the Caribbean island that is also cheaper than before.

Principal Details

Engines type	5 x 9L27/38
Total Net Capacity	12,5 MWe
Wind Turbines	12 x E-44
Total Net Capacity	10,8 MW

World Class Service

Our eyes on your plant

PrimeServ – peace of mind for life

With more than 150 PrimeServ service stations and service partners worldwide and our growing network of PrimeServ Academies, the MAN Diesel & Turbo after-sales organisation is committed to maintaining the most efficient, accessible after-sales organisation in the business. PrimeServ's aim is to provide:

- Prompt, OEM-standard service for the complete life cycle of an installation
- Tuition and qualification of service personnel at our PrimeServ Academies to maximize the availability and viability of a plant
- Rapid, global availability of genuine, 100% quality-assured MAN Diesel & Turbo spare parts via local outlets or our 24-hour hotline.

PowerManagement by MAN Diesel & Turbo

Complementing the PrimeServ after-sales offering is the MAN PowerManagement concept.

MAN PowerManagement packages provide integrated support solutions for all aspects of the running of a power or cogeneration plant. Individually negotiated agreements can cover assistance with – or delegation of – the management of all mechanical, electrical and thermal equipment. In this way the power plant operator gains comprehensive access to the technology, experience, best practices and professional resources of MAN Diesel & Turbo.

In short: PowerManagement by MAN Diesel & Turbo allows you to benefit from our specialist expertise in running a power plant while you concentrate on your own core business.

D2366458EN-N1 Printed in Germany GMC-AUG-07122

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