International Energy Agency

MEASURING SHORT-TERM ENERGY SECURITY

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

IEA member countries:

Australia	France	Korea (Republic of)	Slovak Republic
Austria	Germany	Luxembourg	Spain
Belgium	Greece	Netherlands	Sweden
Canada	Hungary	New Zealand	Switzerland
Czech Republic	Ireland	Norway	Turkey
Denmark	Italy	Poland	United Kingdom
Finland	Japan	Portugal	United States

The European Commission also participates in the work of the IEA.

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ENERGY SECURITY: TOWARDS A COMPREHENSIVE APPROACH

Ensuring energy security has been central to the mission of the International Energy Agency (IEA) since its inception. Founded in response to the oil crisis of 1973, the IEA initially focused on oil supply security. While security of oil supplies remains an important concern, contemporary energy security policies must address a broader range of risks. Threats to energy security come from a variety of natural, economic and political factors, and affect all energy sources and infrastructure.

Since current energy security risks are more diverse and more complex than in the past, understanding vulnerabilities in IEA member countries requires rigorous and comprehensive analysis. In response to this challenge, the IEA has developed the Model of Short-Term Energy Security (MOSES), a tool to evaluate short-term[1] security of energy supply in IEA countries. MOSES' innovative approach makes it possible to combine and interpret indicators related to various aspects of energy security in a systematic, transparent and policy-relevant way. This brochure presents the preliminary results of assessing short-term energy security of supply in IEA countries using MOSES. The IEA is continuously refining and updating both these results and the MOSES methodology.

Interest in energy security has grown recently and many countries undertake their own national-level studies. MOSES can both support and complement these national studies. It provides a systematic generic assessment framework which can be used as a starting point for national studies and can be further supplemented by country-specific indicators and considerations. In addition, MOSES allows for international comparison and interpretation of national energy security challenges. Such a comparison is a pre-requisite for understanding the broader energy security landscape for IEA countries, which, in turn, is necessary for drawing common strategies and responses, as well as for facilitating exchanges of information and policy experience among countries.

This brochure was researched and written by Jessica Jewell with significant contributions from James Simpson under the supervision of Aad van Bohemen and Didier Houssin.

1. Note that in this brochure "short-term" refers to disruptions of days to weeks.

THE MODEL OF SHORT-TERM ENERGY SECURITY (MOSES)

MOSES is a tool to inform energy-security policies through quantifying vulnerabilities of energy systems. It is based on a set of quantitative indicators that measures two aspects of energy security:

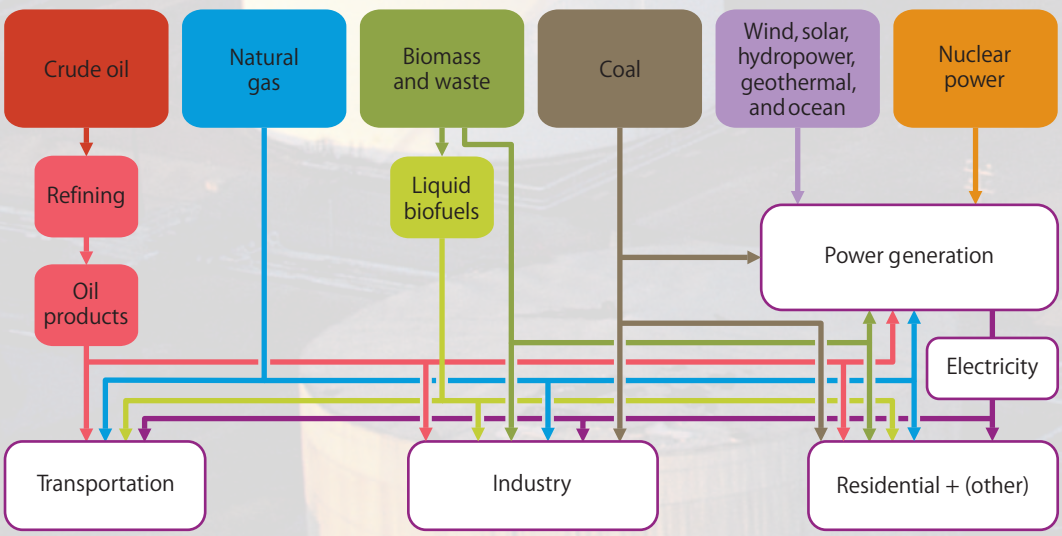
- **risks** of energy supply disruptions; and
- **resilience**, or the ability of a national energy system to cope with such disruptions.

MOSES does not aim to rank countries on the basis of their energy security. Instead, it identifies 'energy security profiles' of individual countries based on their risks and resilience capacities. Nations with similar energy security profiles are grouped together to depict the overall energy security landscape in IEA countries and facilitate policy dialogues on common energy security priorities. MOSES can also be used to track the evolution of national energy security profiles over time, to analyse the effect different policies would have on a given country's energy security and thus aid in identifying national energy policy priorities.

Energy systems approach

MOSES takes an energy systems approach to analysing energy security. Energy systems analysis deals with all parts of the energy system from energy supply to transformation and distribution to end-use energy services. In its current version, MOSES makes the first step of such an approach by analysing vulnerabilities of primary energy sources and how these affect the security of secondary fuels. With its focus on fuels and energy sources, this version of MOSES also lays the groundwork for extending the analysis to security of electricity and end-use sectors.

Energy systems approach in MOSES[2]



2. This version only includes the colour elements but lays the groundwork for electricity and end-use analysis.

THE MODEL OF SHORT-TERM ENERGY SECURITY (MOSES)

Domestic and external risk and resilience

MOSES analyses both risk and resilience connected to **external** factors related to imported energy, as well as **domestic** factors related to domestic production, transformation and distribution of energy. Thus, MOSES includes indicators related to *external risks*, *external resilience*, *domestic risks* and *domestic resilience.*

Dimensions of energy security measured by MOSES

	Risks	Resilience
External	***External risks:*** risks associated with potential disruptions of energy imports	***External resilience:*** ability to respond to disruptions of energy imports by substituting with other suppliers or supply routes.
Domestic	***Domestic risks:*** risks arising in connection with domestic production and transformation of energy	***Domestic resilience:*** domestic ability to respond to disruptions in energy supply such as fuel stocks.

These four dimensions are analysed in MOSES using approximately 30 indicators (shown in the table on the following page) that characterise each primary energy source and secondary fuel. Evaluation of energy supply security using these indicators involves two steps. First, three bands of values – corresponding to low, medium and high vulnerability – are established for each indicator. These bands are based on the observed ranges of the indicator values in IEA countries, as well as on expert judgements about risks and resilience capacities.

In the second step, this categorisation is used to establish an energy security profile for each country. To do that, indicators are combined in a way that takes into account how particular risks may exacerbate each other and how particular resilience capacities may mitigate specific risks. For example, the number of ports or pipelines mitigates risks of imports, but is not relevant for countries with primarily domestic production. In contrast, fuel storage is considered a resilience factor for both domestically-sourced and imported fuels, since it mitigates risks from both sources.

THE MODEL OF SHORT-TERM ENERGY SECURITY (MOSES)

Risk and resilience (res.) indicators used in MOSES

Energy source	Dimension		Indicator	Source(s)
Crude oil	External	Risk	Net-import dependence	IEA
			Weighted average of political stability of suppliers	IEA, OECD
		Res.	Entry points (ports and pipelines)	IEA
			Diversity of suppliers	IEA
	Domestic	Risk	Proportion of offshore production	IEA
			Volatility of domestic production	IEA
		Res.	Stock level	IEA
Oil products	External	Risk	Net-import dependence	IEA
		Res.	Diversity of suppliers	IEA
			Entry points (ports and pipelines)	IEA
	Domestic	Res.	Number of refineries	IEA
			Flexibility of refining infrastructure	IEA
			Stock level	IEA
Natural gas	External	Risk	Net-import dependence	IEA
			Weighted average of political stability of suppliers	IEA, OECD
		Res.	Entry points (LNG ports and pipelines)	IEA
			Diversity of suppliers	IEA
	Domestic	Risk	Proportion of offshore production	IEA
		Res.	Daily send-out capacity from underground and LNG storage	IEA
			Natural gas intensity	IEA, World Bank
Coal	External	Risk	Net-import dependence	IEA
		Res.	Entry points (ports and pipelines)	IEA
			Diversity of suppliers	IEA
	Domestic	Risk	Proportion of mining that is underground	various national sources
Hydropower	Domestic	Risk/ Res.	Annual volatility of production	IEA
Nuclear power	Domestic	Risk	Unplanned outage rate	IAEA
			Average age of nuclear power plants	IAEA
		Res.	Diversity of reactor models	IAEA
			Number of nuclear power plants	IAEA

For more information on indicator definition and a detailed methodology, readers are referred to the IEA Working Paper: *The IEA Model of Energy Security (MOSES): Primary energy sources and secondary fuels* (forthcoming, Fall 2011).

THE MODEL OF SHORT-TERM ENERGY SECURITY (MOSES)

Limitations and future work

Any study of energy security faces a series of choices and MOSES is no exception. The focus on short-term physical security of primary sources and secondary fuels excludes notions that are more relevant in medium or long-term perspectives, such as the environmental impact of different energy sources and systems, rapidly growing demand, and the depletion of natural resources. Similarly, energy security aspects related to what some call the "economic" or "affordability" dimension of energy security, such as the level and volatility of energy prices, are not captured because MOSES focuses on physical security of supply.

Since MOSES relies on quantitative indicators, some institutional and investment factors are excluded. The security of an energy system is not limited to the state of its infrastructure (the primary focus of MOSES), but also to the effectiveness of its policies and regulations as well as the market structure and the investment climate. While governance factors can be important for energy security, they are not easily quantified and thus only indirectly reflected in MOSES.

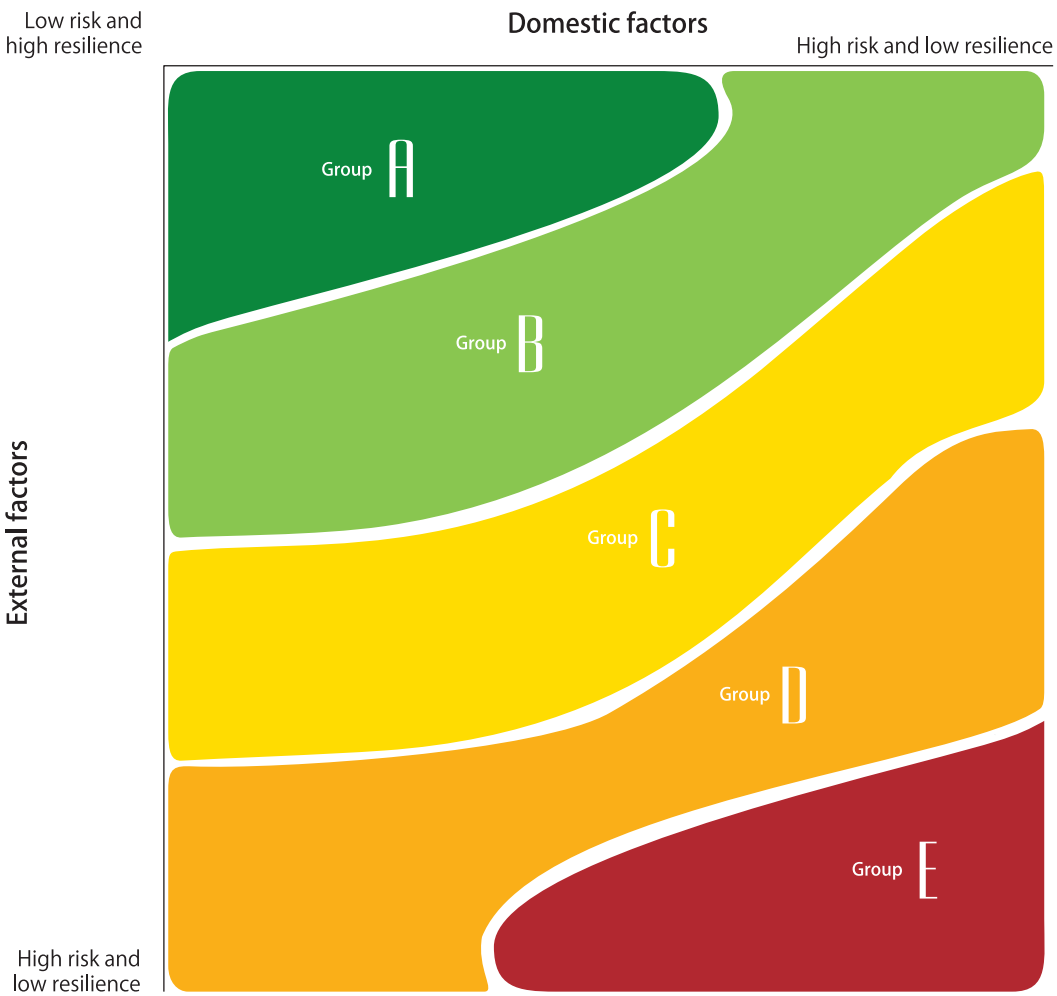
MOSES aims to evaluate security of supply of individual primary energy sources and secondary fuels. It is not designed to compare security of supply across different energy sources, nor to produce an overall "energy security index" spanning several fuels and carriers. Consequently, it cannot be used to compare the "overall" energy security of countries, although the situation with respect to specific sources and fuels can easily be compared.

Additionally, it is important to note that MOSES focuses on security of supply. While security of supply is an important element of energy security, ultimately consumers and policy-makers alike are most concerned about the security of energy services. Thus, incorporating electricity and then end-uses into MOSES will be key future steps in providing policy-relevant analysis of energy security.

RESULTS OF EVALUATING SHORT-TERM ENERGY SECURITY

The remaining part of this brochure reports the results of evaluating short-term energy security in IEA countries using the MOSES methodology. Each page describes the vulnerabilities related to a different primary energy source or secondary fuel. The diagrams on the following pages illustrate how the fuel- or source-specific risk and resilience factors are accounted for in evaluating security of supply. The tables following the diagrams describe three to five energy security profiles (made by combinations of risk and resilience indicators) for each energy source or fuel. The energy security profiles are marked by letters A to E, generally moving from lower risks/higher resilience profiles (higher energy security), to higher risk/lower resilience profiles (lower energy security) as schematically shown in the figure below. The number of IEA countries with each particular energy security profile is also reported, which depicts the energy security landscape for IEA countries for each primary energy source or secondary fuel.

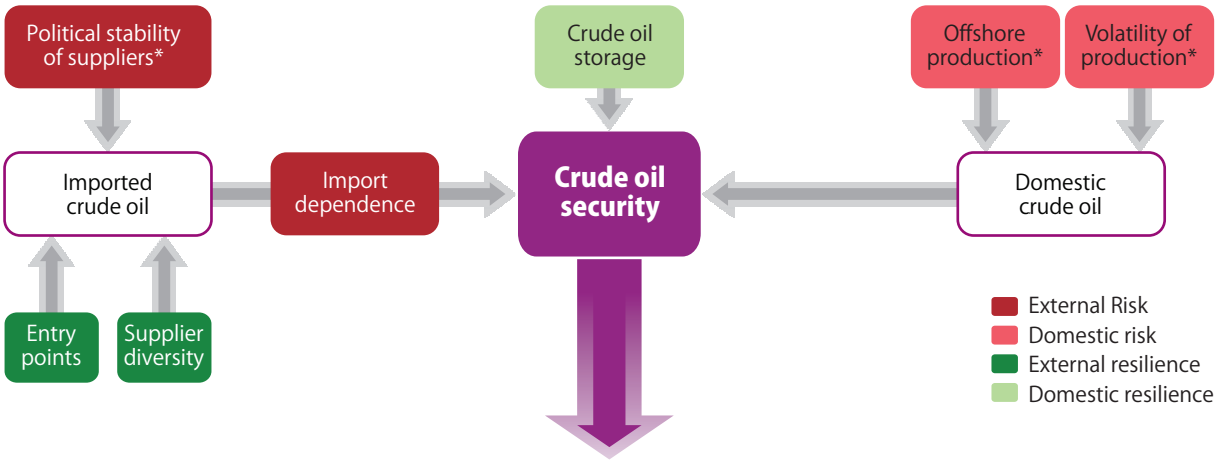
Schematic diagram for identifying energy security profiles in IEA countries



CRUDE OIL

The analysis of crude oil security is based on seven indicators. First, countries are divided according to their net crude oil import dependence. Net-exporters and countries with low import dependency are assigned to group A. The remaining countries with high import dependence are grouped according to their external resilience (*i.e.* the number of entry points and the diversity of suppliers) and domestic resilience (*i.e.* the level of strategic crude oil stocks).

Schematic diagram for crude oil analysis with indicators



Summary of findings on crude oil security

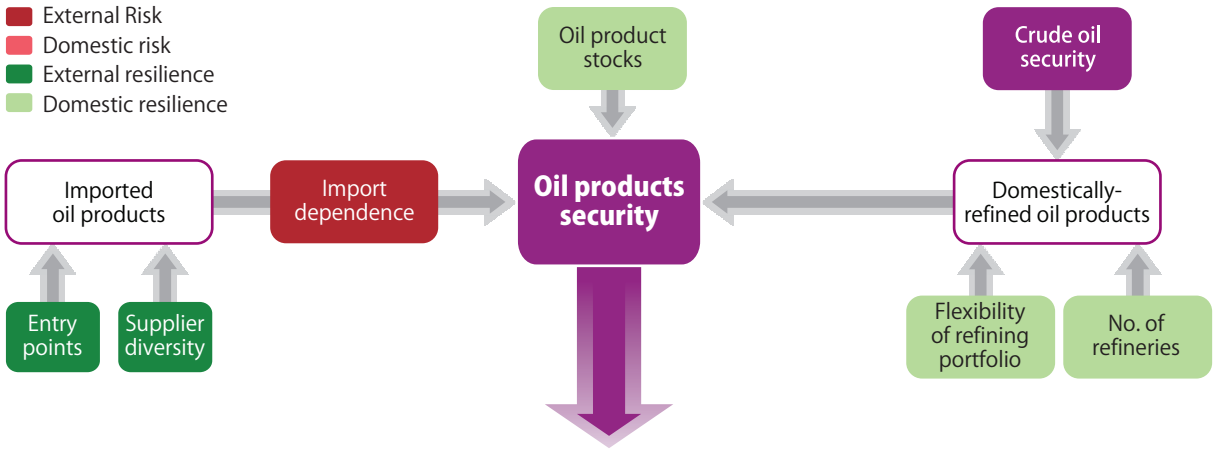
Group	Countries that:	No. of countries
A	**Export crude oil** or **import** ≤15% of their crude oil consumption.	5
B	**Import 40-65%** of their crude oil consumption or **Import ≥80%** of their crude oil consumption and have ▪ ≥5 crude oil ports, high supplier diversity and ≥55 days of crude oil storage.	4
C	**Import ≥80%** of their crude oil consumption and have ▪ ≥5 crude oil ports, high supplier diversity and <50 days of crude oil storage or ▪ 2-4 crude oil ports, high supplier diversity and >20 days of crude oil storage.	9
D	**Import ≥80%** of their crude oil consumption and have: ▪ 2-4 crude oil ports, high supplier diversity and ≤15 days of crude oil storage or ▪ 2 crude oil ports or 3 crude oil pipelines, low supplier diversity and ≥15 days crude oil storage or ▪ 1-2 crude oil pipelines or 1 crude oil port and have either ▪ medium to high supplier diversity and ≥15 days of crude oil storage or ▪ low supplier diversity and ≥55 days of crude oil storage.	6
E	**Import ≥80%** of their crude oil consumption and have ▪ 1-3 crude oil pipelines or 1 crude oil port and ≤15 days of crude oil storage or ▪ 1-2 crude oil pipelines, low supplier diversity and <50 days of crude oil storage.	3

Notes: This table only includes 27 countries because Luxembourg does not use crude oil. Indicators with an asterisk (*) are used in ordering countries within each group but not in distinguishing between groups.

OIL PRODUCTS

MOSES analyses the security of oil products for three categories of products: gasoline (motor), middle distillates (which includes diesel and most kerosene products) and "other" (such as fuel oil, certain types of jet fuel, and naphtha). Security of each of these product categories is evaluated based on the results of the crude oil analysis reported in the previous section, as well as six additional indicators. For countries that refine more than 55% of their oil products domestically, the vulnerability of their oil products primarily depends on the vulnerability of their crude oil supply, as well as the number and flexibility of their refineries. In contrast, for countries importing more than 45% of their oil products, the analysis also accounts for the vulnerabilities of these imports.[3] For all countries, the average number of days of forward demand of oil product stocks (for 2010) is used as an indicator of resilience.

Schematic diagram for oil products security with indicators



Summary of findings on gasoline security

Group	Countries that:	No. of countries
A	**Import** ≤45% of their gasoline consumption and are ▮ in Crude oil groups A or B with ≥6 weeks of gasoline stocks or ▮ in Crude oil groups C or D with a moderate to highly flexible refining portfolio and ≥9 weeks of gasoline stocks.	11
B_1	**Import** ≤45% of their gasoline consumption and are ▮ in Crude oil groups A or B with <6 weeks of gasoline stocks or ▮ in Crude oil group C with a moderate to highly flexible refining portfolio and 3-6 weeks of gasoline stocks.	9
B_2	**Import** ≤45% of their gasoline consumption and are ▮ in Crude oil groups D or E with one highly flexible refinery and ≥9 weeks of gasoline stocks or **Import** >45% of their gasoline consumption and have ▮ a moderate supplier diversity and ≥9 weeks of gasoline stocks.	5
C	**Import** >45% of their gasoline consumption and have ▮ 6-9 weeks of gasoline stocks and either ≥6 sea ports for gasoline imports with low supplier diversity or 1-2 oil product pipelines with moderate supplier diversity.	2
D	**Import** 100% of their gasoline consumption and have ▮ 3-6 weeks of gasoline stocks, one oil product pipeline and low supplier diversity.	1

3. Political stability of suppliers is not included in external risks because it was found to be an insignificant factor since suppliers of oil products to IEA countries are in general more stable than suppliers of crude oil.

OIL PRODUCTS

Summary of findings on middle distillates

Group	Countries that:	No. of countries
A	**Import** ≤45% of their middle distillates consumption and ▪ have ≥9 weeks of middle distillates stocks and are either ▫ in Crude oil groups A through C or ▫ in Crude oil group D with a highly flexible refining portfolio and at least 2 refineries.	9
B_1	**Import** ≤45% of their middle distillates consumption and are ▪ in Crude oil groups A through C with ≥3 weeks of middle distillates stocks.	10
B_2	**Import** ≤45% of their middle distillates consumption and are ▪ in Crude oil groups D or E with a moderate to highly flexible refining portfolio and ≥6 weeks of middle distillates stocks or **Import** >45% of their middle distillates consumption with ≥9 weeks of middle distillates stocks and either moderate supplier diversity or ≥5 oil products ports.	5
C	**Import** ≤45% of their middle distillates consumption and in Crude oil group E with 1 highly flexible refinery and ≥6 weeks of middle distillates stocks.	1
D	**Import** >45% of their middle distillates consumption with moderate supplier diversity and 3-6 weeks of middle distillates stocks.	2
E	**Import** 100% of their middle distillates consumption through 1 pipeline with low supplier diversity and ≤3 weeks of middle distillates stocks.	1

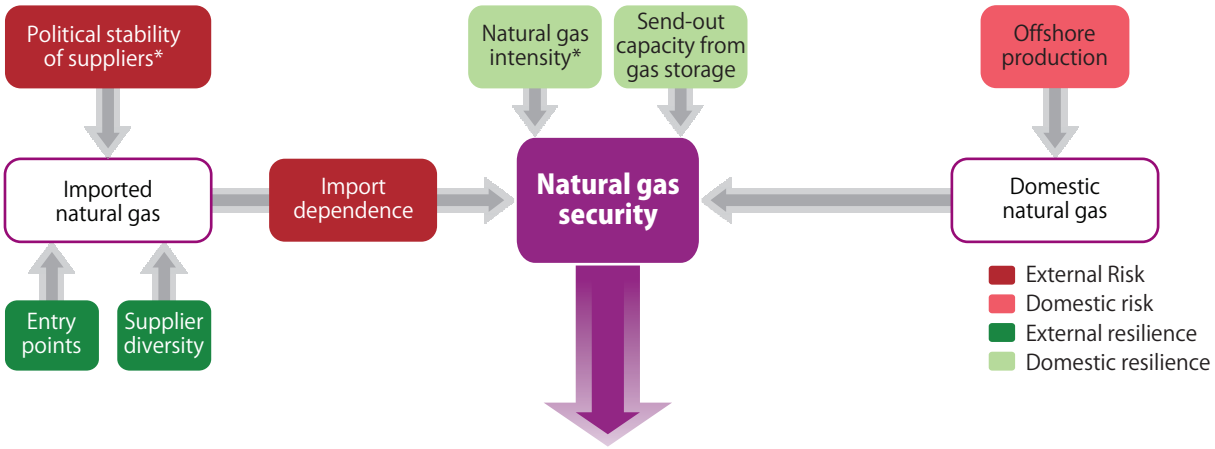
Summary of findings on other oil products security

Group	Countries that:	No. of countries
A	**Import** ≤45% of their other oil products consumption and are ▪ in Crude oil groups A or B with ≥6 weeks of other oil products stocks or ▪ in Crude oil group C with either ▫ a highly flexible refining portfolio and ≥6 weeks other oil products stocks or ▫ a limited to moderately flexible refining portfolio with ≥ 9 weeks of other oil products stocks.	4
B	**Import** ≤45% of their other oil products consumption and are ▪ in Crude oil groups A or B with <6 weeks of other oil products stocks or ▪ in Crude oil group C with moderate flexibility of refining and 3-9 weeks of other oil products stocks.	10
C_1	**Import** ≤45% of their other oil products consumption and are ▪ in Crude oil group C with either ▫ a moderately to highly flexible refining portfolio and <3 weeks of other oil products stocks or ▫ a relatively inflexible refining portfolio with ≥3 weeks of other oil products stocks or ▪ in Crude oil group D with a highly flexible refining portfolio and at least 2 refineries.	4
C_2	**Import** >45% of their other oil products consumption with ≥5 oil product ports and ≥6 weeks of other oil products stocks.	2
D	**Import** ≤45% of their other oil products consumption and are ▪ in Crude oil groups D or E with either ▫ a moderately flexible refining portfolio and 3-6 weeks of other oil products stocks or ▫ a highly flexible refining portfolio and <3 weeks of other oil products stocks or **Import** >45% of their other oil products consumption with moderate supplier diversity and <3 weeks of other oil products stocks.	6
E	**Import** 100% of their other oil products consumption with low supplier diversity and <3 weeks of other oil products stocks.	2

NATURAL GAS

Natural gas security is evaluated with seven indicators. This analysis follows a similar logic to the analysis of crude oil security. First, countries are divided according to their net-import dependence with net-exporters and low importers assigned to group A. Second, countries with high import dependence are grouped according to their external and domestic resilience factors, such as the number of LNG terminals, the diversity of suppliers and the levels of natural gas storage.

Schematic diagram for natural gas security with indicators



Summary of findings on natural gas security

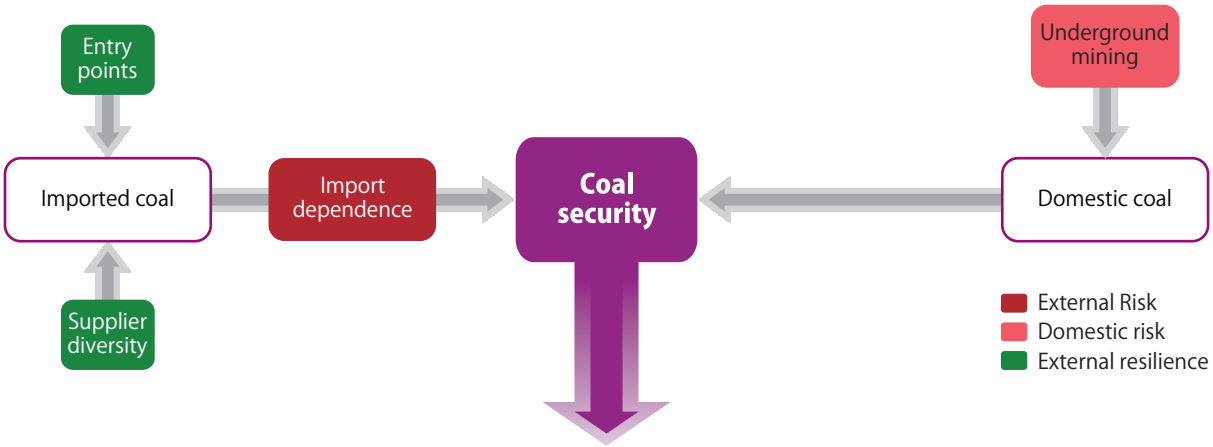
Group	Countries that:	No. of countries
A	**Export natural gas** or **Import** ≤10% of their natural gas supply or **Import** 10%-40% with ≥5 pipelines, ≥3 LNG ports, and a high supplier diversity.	8
B	**Import** ≥70% of their natural gas supply and have ▮ ≥5 pipelines and/or ≥3 LNG ports, a high supplier diversity, and maximum send-out capacity from gas storage ≥50% peak-daily demand.	4
C	**Import** ≥70% of their natural gas supply and have ▮ ≥5 pipelines and/or ≥3 LNG ports, a high supplier diversity, and maximum send-out capacity from gas storage <50% of peak-daily demand or ▮ 3-4 pipelines and/or 1-2 LNG ports, a medium to high supplier diversity, and maximum gas storage send-out capacity ≥50% peak-daily demand or ▮ ≤4 pipelines or ≤2 LNG ports, low to medium supplier diversity, and maximum send-out capacity ≥100% of peak-daily demand.	8
D	**Import** ≥70% of their natural gas supply with 3-5 pipelines and/or 1-2 LNG ports and ▮ medium to high supplier diversity and maximum send-out capacity from gas storage <50% of peak-daily demand or ▮ low to medium supplier diversity and maximum send-out capacity ≥50% of peak-daily demand.	5
E	**Import** ≥70% of their natural gas supply and have ▮ 3-4 pipelines and/or 1-2 LNG ports with low supplier diversity and maximum send-out capacity <50% of peak-daily demand.	3

Note: Indicators with an asterisk (*) are used in ordering countries within each group but not in distinguishing between groups.

COAL

The security of supply of coal is analysed based on four indicators. The logic of the analysis is similar to that used for the supply security of crude oil and natural gas. In the first step, countries are divided into those primarily relying on coal imports and those primarily relying on domestic coal production. For coal importers, further discriminating factors are supplier diversity and the number of ports and railways where coal can be imported. The final grouping factor is the share of coal from underground mining (for domestic production), which is considered more risky.

Schematic diagram for coal security with indicators



Summary of findings on coal security

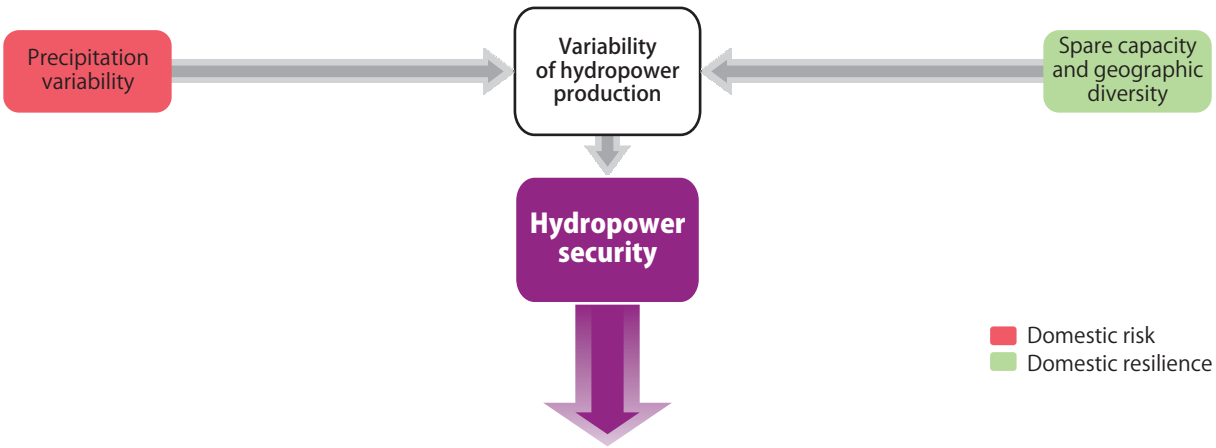
Group	Countries that:	No. of countries
A	**Export coal** or **Import 30-60%** of coal with ▮ the share of underground mining ≤40%.	12
B	**Import 30-60%** of coal with ▮ the share of underground mining >40%.	2
C	**Import ≥70%** of coal with ▮ medium to high supplier diversity and ≥5 river or sea ports for coal import.	8
D	**Import ≥70%** of coal with ▮ medium to high supplier diversity and 3-4 river or sea ports for coal import.	5
E	**Import ≥70%** of coal with ▮ low supplier diversity and ≤2 sea or river ports.	1

HYDROPOWER

Geothermal, hydropower, solar, wind and ocean energy are harnessed domestically and widely viewed as increasing supply security by reducing import dependency and increasing diversity in a country's energy portfolio. With the exception of hydropower and geothermal energy, these sources exhibit short-term variability (*i.e.* from hours to days), which is planned for in the design of the electricity system. Thus, the short-term security of supply of these sources is closely entangled with the security of electricity systems. Since MOSES focuses on supply security, it does not address risks associated with the integration of renewable energy sources into the electricity system. [4]

MOSES only analyses security of hydropower. Hydropower is evaluated using the average annual volatility of hydropower production (1990-2009). This indicator reflects both weather variability (risk) and hydropower reservoirs (resilience).

Schematic diagram for hydropower security with indicators



Summary of findings on hydropower security

Group	Countries with:	No. of countries
A	Volatility of hydropower production ≤11%.	12
B	Volatility of hydropower production 12-21%.	12
C	Volatility of hydropower production ≥22%.	4

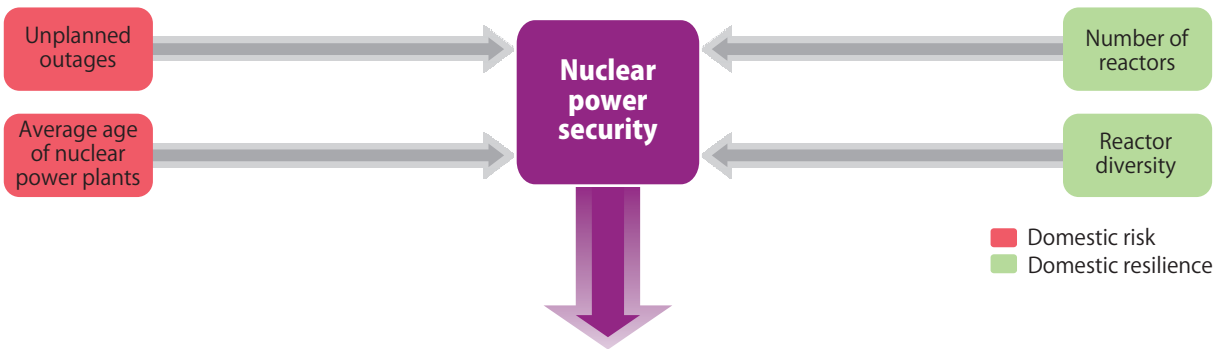
MOSES also has modules on biomass and biofuels, which are not presented in this brochure, but readers are invited to read the IEA Working Paper *The IEA Model of Energy Security (MOSES): Primary energy sources and secondary fuels* (forthcoming fall 2011).

4. The IEA is actively engaged in research in the areas of electricity security and variable resources; a recent IEA publication discusses in detail the technological, geographical, institutional and market factors affecting variable renewable deployment and integration in grids (*Harnessing Variable Renewables*, 2011).

NUCLEAR POWER

The analysis of short-term security of nuclear power concentrates on domestic rather than external factors.[5] The main risk indicator is the unplanned outage rate of nuclear power plants. The main resilience indicator is the number of nuclear power plants. A larger number of nuclear power plants makes the energy system less vulnerable to a risk (*i.e.* technical failure or a natural event), which can affect the operation of any single plant. MOSES also includes the analysis of two additional nuclear energy indicators: the average age of nuclear power plants (risk) and the diversity of reactor models (resilience). However, these indicators do not affect the categorisation of countries based on the outage rate and the number of reactors. MOSES does not evaluate the safety of nuclear power plants.

Schematic diagram for nuclear power security with indicators



Summary of findings on nuclear power security

Group	Countries that have:	No. of countries
A	An unplanned outage rate ≤3% with ▮ ≥15 nuclear power plants and a moderate to high diversity of reactor models.	2
B	An unplanned outage rate ≤3% with ▮ 4-10 nuclear power plants and a moderate to high diversity of reactor models..	4
C	An unplanned outage rate >3% with ▮ ≥ 15 nuclear power plants and a moderate to high diversity of reactor models.	5
D	An unplanned outage rate >3% with ▮ 4-10 nuclear power plants and a moderate diversity of reactor models.	4
E	An unplanned outage rate ≤3% with ▮ 1 relatively old nuclear power plant.	1

5. External factors are less relevant to short-term nuclear energy supply security since nuclear power plant refuelling typically provides two to three years of nuclear fuel stocks.

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