Category		Title
NFR:	1.B.1.a	Fugitive emissions from solid fuels: coal mining and handling
SNAP:	0501 050101 050102 050103	Extraction and first treatment of solid fossil fuels Open cast mining Underground mining Storage of solid fuel
ISIC:		
Version	Guidebook 2019	

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Contents

1 Overview

This chapter covers emissions from the mining and handling of coal. Peat and other solid fuels are excluded from this chapter. The subsequent treatment of coal, such as fuel conversion, coking, gasification and liquefaction are not covered by this chapter. These processes are included in the related chapters elsewhere in the Guidebook.

The extraction and treatment of coal result mainly in emissions of methane. However, also non-methane volatile organic compounds (NMVOC), particulate matter and CO_2 are emitted. Emissions of the methane and CO_2 are not covered by the Guidebook. Guidance for reporting these greenhouse gases can be found in the Intergovernmental Panel on Climate Change (IPCC) Guidelines.

2 Description of sources

2.1 Process description

Coalfields contain a proportion of highly volatile material which is released during the working, extraction and storage of coal. The volatile material is known as firedamp, made up primarily of methane, although other compounds are also present in minor amounts.

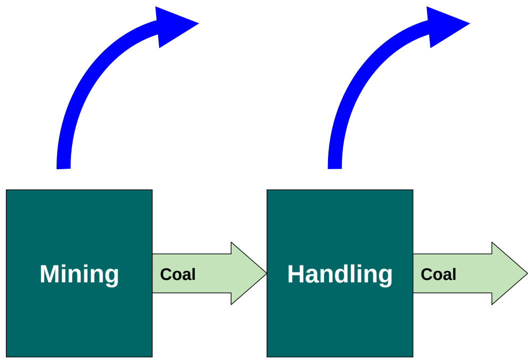
The release of firedamp often results in an emission to air as it not always economical to contain the gas for flaring or use as a fuel.

During coal extraction, the following processes connected with firedamp release can be identified:

- developing access to the coal deposit and its preparation for extraction;
- coal extraction and transport on the surface;
- coal processing, disposal, transport and crushing before final use;
- deposit de-methaning before, during and after its excavation;
- disposal of spoils from the coal extraction system.

Air containing methane is usually emitted to the atmosphere because its use as fuel or for combustion purposes is not economically viable, mainly due to the high dilution.

Figure 2-1 Process scheme for source category 1.B.1.a Coal mining and handling



Releases of particulate matter occur during mining activities, including drilling, and during storage and handling, including loading, wind erosion, equipment traffic, load out and any drop related operations.

2.2 Techniques

Two types of mining operations are considered in this chapter — deep mines and open cast mines. In addition, it is important to note that coal varies considerably from one field to another, depending on its age and geological location. The proportion of firedamp associated with the different types of mining and the different types of coal have shown considerable variation. Attempts to model the relationship between the proportion of firedamp and factors such as depth of coal seam, nature of coal and local geology have shown some correlations although the associated uncertainty is very large.

Once coal is extracted it may be stored, transported internally or exported, or a combination of all three. Associated gaseous emissions continue to occur and it is thought that these will be related to the coal type, the size of the coal pieces, and the mechanical disturbance during handling, etc.

2.3 Emissions and controls

This section discusses the emissions from coal mining and handling in general. The discussion includes emissions of CO_2 and CH_4, although these are not covered by the scope of this Guidebook. Emissions of these greenhouse gases must be reported following the IPCC Guidelines (IPCC, 2006).

In technological processes performed in underground workings, methane is released which, unless taken in by the de-methaning systems, is discharged to the atmosphere by the ventilation systems of the mines. The ventilation systems are the primary and main methane emission source from coal mines. Emission from the ventilation systems is described as ventilation emission. Methane, in this case called ‘residual gas’, is also contained in the coal extracted to the surface and released during the extraction processes. Emission related to these processes is called emission from extraction processes. This emission constitutes the second methane emission source in coal mining.

Some methane is also contained in the bedrock extracted to the surface with coal and gets released during bedrock disposal. This is the third source of methane emission. The fourth source is the de-methaning systems. The methane collected by these systems is not totally utilised or combusted in flames and some or all of the volume is emitted as 'whistler' to the atmosphere.

In open-cast coal extraction, there are two main sources of ventilation emission:

- emission from the extracted coal;
- emission from the deposits coating the working.

The primary emission of firedamp is believed to occur during the extraction of deep mine coal. Open cast mining, since it involves the extraction of coal seams close to the surface and the handling and storage of coal, are not considered to be as important.

In many cases, firedamp is actively removed from the coalfield by various methods, normally described collectively as methane drainage. This is primarily for reasons of safety. As an example, in the UK in 1988, 16 % of the firedamp released by deep mining was vented from methane drainage systems, 11 % was captured and used as fuel, 61 % was emitted with ventilation air and about 12 % was removed in the mined coal.

Data from Russia (Tsibulski, 1995) indicates that the balance of methane emissions from coal seams and enclosing rocks is distributed as follows:

- 60 % emitted to atmosphere from mines together with ventilation air;
- 12 % captured in mines and if not utilised then also emitted;
- 15 % emitted to atmosphere from coal extracted to the surface;
- 13 % remains in the seam and surrounding rock.

Firedamp may be removed before the mining of a coal seam (pre-drainage) or as a consequence of mining (post-drainage). The latter approach is likely to be the most common.

2.3.1 Post-drainage technologies

Cross-measures methane drainage

Boreholes are drilled at an angle above, and sometimes below, the mined-out area, which collapses as the coal is removed. The boreholes are drilled close to the coalface and linked to a common pipe range. Suction is applied to the pipe range to draw the gas to a discharge point. Depending on circumstances and geology, 35 % to 75 % of the total gas released in an underground district can be captured at purities ranging from 30 % to 70 %. Higher purity gas is generally not available.

Surface 'gob' well post-drainage

This technology is well established in the US. Gas is drained via surface boreholes from the de-stressed zone above a caving 'long-wall' face. The gas produced is generally of high purity. The principle disadvantages are high drilling costs and surface environmental planning restrictions.

Other methods of post drainage include super-adjacent drainage heading (sewer road) and super adjacent guided long-hole. Both methods involve driving long boreholes or roadways adjacent to the worked coalface (typically with 30 m to 40 m). The applicability is very much dependent on local geology.

2.3.2 Pre-drainage technologies

In-seam boreholes

This requires drilling boreholes parallel to the undisturbed coalface. The success of this technique depends on the permeability of the coal and the gas pressure. The higher the permeability and gas pressure, the greater the efficiency.

Hydrofracced surface boreholes

This technique involves hydraulically fracturing a sequence of productive horizons, injecting sand into the fractures and connecting the fractures to a well-head assembly. Gas and other fluids occupy the sand-filled fractures and enter the well-head assembly without encountering excessive resistance. The technique has been applied in the US, but is also very dependent on geology.

2.3.3 Extracting pollutants from the ventilation air

Besides active drainage of gas, removal also occurs as a result of the ventilation of the mine. Using the ventilation air as feed air for boilers or engines may control organic compounds associated with ventilation air. Liquefaction of gases and catalytic or biological oxidation are generally inappropriate for low concentrations of organic compounds found in ventilation air.

2.3.4 Utilisation of firedamp

Reducing emissions by flaring

Flaring is not a common method for controlling firedamp, since to practice this safely is often prohibitively expensive.

Reducing emissions by using gas as a fuel

This is not a new concept. Since recovering combustible material from ventilation air is expensive, the technique applies primarily to actively drained firedamp. Whether or not firedamp is used as a fuel depends primarily on financial considerations, particularly if ensuring a continuous supply requires backup fuels such as liquid petroleum gas, and if competitor fuels are readily available.

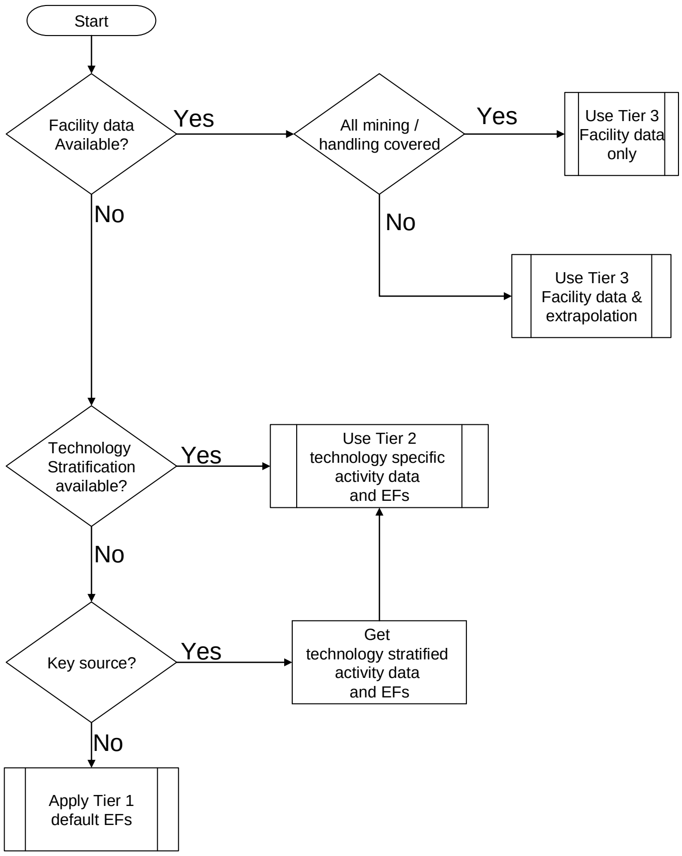
3 Methods

3.1 Choice of method

Figure 3-1 presents the procedure to select the methods for estimating emissions from coal mining and handling. The basic idea is:

- if detailed information is available, use it;
- if the source category is a key category, a Tier 2 or better method must be applied and detailed input data must be collected. The decision tree directs the user in such cases to the Tier 2 method, since it is expected that it is more easy to obtain the necessary input data for this approach than to collect facility level data needed for a Tier 3 estimate;
- the alternative of applying a Tier 3 method, using detailed process modelling, is not explicitly included in this decision tree. However, detailed modelling will always be done at facility level and results of such modelling could be seen as ‘facility data’ in the decision tree.

Figure 3-1 Decision tree for source category 1.B.1.a Coal mining and handling



3.2 Tier 1 default approach

3.2.1 Algorithm

The Tier 1 approach for coal mining and handling uses the general equation:

$$E_{pollutant} = AR_{production} \times EF_{pollutant} \quad (1)$$

where:

$E_{pollutant}$ = the emission of the specified pollutant,

$AR_{production}$ = the activity rate for the coal mine production,

$EF_{pollutant}$ = the emission factor for this pollutant.

This equation is applied at the national level, using annual totals for coal mining and handling. The total mass of coal produced by underground or open cast mining can be used as activity statistics.

The Tier 1 emission factors assume an averaged or typical technology and abatement implementation in the country and integrate all different sub-processes within the coal mining and handling process.

In cases where specific abatement options are to be taken into account a Tier 1 method is not applicable and a Tier 2 ort Tier 3 approach must be used.

3.2.2 Default emission factors

Table 3-1 provides the default emission factors for NMVOC and particulate matter (TSP, PM_{10} and $PM_{2.5}$) from coal mining and handling. Emissions of CH_4 and CO_2 are greenhouse gas emissions and it is good practice to report these in compliance with the IPCC Guidelines (IPCC 2006).

The NMVOC factor is based on an assessment of the emission factors for methane from an earlier version of the Guidebook, in combination with a species profile (Williams, 1993). This profile suggests an average NMVOC content between 0 and 12 % in the firedamp. The emission factors have been recalculated in terms of mass per mass of coal produced.

The PM emission factors are estimated as the sum of Tier 2 factors for open cast mining and handling of coal (Table 3-2 and 3-6).

Table 3-1 Tier 1 emission factors for source category 1.B.1.a Coal mining and handling

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.B.1.a	Coal mining and handling			
Fuel	NA				
Not applicable	NOx, CO, SOx, NH3, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB, HCH				
Not estimated	Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, BC				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	0.8	kg/Mg coal	0	6.4	EMEP/EEA (2006)
TSP	0.089	kg/Mg coal	0.0091	0.91	US EPA (1998), Visschedijk et al. (2004) applied in Peutz (2006)
PM10	0.042	kg/Mg coal	0.0044	0.44	US EPA (1998), Peutz (2006), Vrins (1999)
PM2.5	0.005	kg/Mg coal	0.0007	0.07	US EPA (1998), Visschedijk et al. (2004) applied in Peutz (2006)

The uncertainty in the Tier 1 emission factor for NMVOC is assumed to be large, because it is based on measurements of emissions of methane from this source.

3.2.3 Activity data

The relevant activity statistic for Tier 1 is the total mass of coal produced by underground mining and/or the total tonnage of coal produced by opencast mining.

3.3 Tier 2 technology-specific approach

3.3.1 Algorithm

The Tier 2 approach is similar to the Tier 1 approach. To apply the Tier 2 approach, both the activity data and the emission factors need to be stratified according to the different techniques that may occur in the country.

The approach followed to apply a Tier 2 approach is as follows:

Stratify the coal mining/storage/handling in the country to model the different product and process types occurring in the national coal mining industry into the inventory by :

- defining the production using each of the separate product and/or process types (together called 'technologies' in the formulae below) separately, and
- applying technology specific emission factors for each process type:

$$E_{pollutant} = \sum_{technologies} AR_{production,technology} \times EF_{technology,pollutant} \quad (2)$$

where:

$AR_{production,technology}$ = the production rate within the source category, for the specific technology,

$EF_{technology,pollutant}$ = the emission factor for this technology and this pollutant.

A country where only one technology is implemented will result in a penetration factor of 100 % and the algorithm reduces to:

$$E_{pollutant} = AR_{production} \times EF_{technology,pollutant} \quad (3)$$

where:

$E_{pollutant}$ = the emission of the specified pollutant,

$AR_{production}$ = the activity rate for coal mining,

$EF_{pollutant}$ = the emission factor for this pollutant.

The emission factors in this approach will still include all sub-processes with the coal mining and handling process.

3.3.2 Technology-specific emission factors

This section presents the Tier 2 emission factors for source category 1.B.1.a, for both underground and open cast mining. The emission factors are based on high methane emission factor data. It is good practice to use this high factor if no data on the methane contents are available.

As for the Tier 1 default emission factor for NMVOC emission from coal mining and handling, the Tier 2 emission factors for NMVOC emissions are based on the methane emission factors available in an older version of the Guidebook, in combination with data on the composition of the firedamp. Because of the high uncertainty in the latter, care must be taken when applying these emission factors.

Table 3-1 (open cast mining) and Table 3- (underground mining) include the emissions from drilling and the first handling of coal. Table 3-4, Table 3-5 and **Error! Reference source not found.** present e mission factors for the subsequent storage (uncontrolled and controlled) and handling of coal.

Table 3-2 Tier 2 emission factors for source category 1.B.1.a Coal mining and handling, Open cast mining

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.1.a	Coal mining and handling			
Fuel	NA				
SNAP (if applicable)	050101	Open cast mining			
Technologies/Practices					
Region or regional conditions					
Abatement technologies					
Not applicable	NOx, CO, SOx, NH3, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB, HCH				
Not estimated	Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, BC				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	0.2	kg/Mg coal produced	0	0.5	EMEP/EEA (2006)
TSP	0.082	kg/Mg coal produced	0.0082	0.82	US EPA (1998)
PM10	0.039	kg/Mg coal produced	0.0039	0.39	US EPA (1998)
PM2.5	0.006	kg/Mg coal produced	0.0006	0.06	US EPA (1998)

Table 3-3 Tier 2 emission factors for source category 1.B.1.a Coal mining and handling, underground mining

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.1.a	Coal mining and handling			
Fuel	NA				
SNAP (if applicable)	050102	Underground mining			
Technologies/Practices					
Region or regional conditions					
Abatement technologies					
Not applicable	NOx, CO, SOx, NH3, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB, HCH				
Not estimated	Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, BC				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	3	kg/Mg coal produced	0	6.4	EMEP/EEA (2006)
TSP	0.59	kg/hole drilled	0.059	5.9	US EPA (1998)

PM10	0.28	kg/hole drilled	0.028	2.8	US EPA (1998)
PM2.5	0.04	kg/hole drilled	0.004	0.4	US EPA (1998)

Storage of coal

Table 3.4 and 3.5 present emission factors for storage of coal based on measurements and methodology developed by the Netherlands (Peutz (2006)). Two sets of emission factors are provided for uncontrolled and controlled storage of coal, respectively.

Table 3-4 Tier 2 emission factors for source category 1.B.1.a Coal Mining and Handling, Storage of coal, uncontrolled

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.1.a	Coal mining and handling			
Fuel	NA				
SNAP (if applicable)					
Technologies/Practices	Storage of coal				
Region or regional conditions					
Abatement technologies	Uncontrolled				
Not applicable	NOx, CO, SOx, NH_3, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB, HCH				
Not estimated	NMVOC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, BC				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
TSP	10.25	Mg/ha/year	1.025	102.5	Visschedijk et al. (2004) applied in Peutz (2006)
PM10	4.1	Mg/ha/year	0.41	41	Peutz (2006), US EPA (2006)
PM2.5	0.41	Mg/ha/year	0.041	4.1	Visschedijk et al. (2004) applied in Peutz (2006)

Table 3-5 Tier 2 emission factors for source category 1.B.1.a Coal Mining and Handling, Storage of coal, controlled

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.1.a	Coal mining and handling			
Fuel	NA				
SNAP (if applicable)					
Technologies/Practices	Storage of coal				
Region or regional conditions					
Abatement technologies	Controlled				
Not applicable	NOx, CO, SOx, NH3, BC, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB, HCH				
Not estimated	NMVOC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
TSP	1.025	Mg/ha/year	0.1025	10.25	Visschedijk et al. (2004) applied in Peutz (2006)
PM10	0.41	Mg/ha/year	0.041	4.1	Peutz (2006), Vrins (1999)
PM2.5	0.041	Mg/ha/year	0.0041	0.41	Visschedijk et al. (2004) applied in Peutz (2006)

Handling of coal

Table 3.6 presents emission factors for handling of coal based on measurements and methodology developed by the Netherlands (Peutz (2006)).

Table 3-6 Tier 2 emission factors for source category 1.B.1.a Coal Mining and Handling, Handling of coal, unabated

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.1.a	Coal mining and handling			
Fuel	NA				
SNAP (if applicable)					
Technologies/Practices	Handling of coal				
Region or regional conditions					
Abatement technologies	Unabated				
Not applicable	NOx, CO, SOx, NH3, BC, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB, HCH				
Not estimated	NMVOC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
TSP	7.5	g/Mg coal	0.75	75	Visschedijk et al. (2004) applied in Peutz (2006)
PM10	3	g/Mg coal	0.3	30	Peutz (2006), Vrins (1999)
PM2.5	0.3	g/Mg coal	0.03	3	Visschedijk et al. (2004) applied in Peutz (2006)

3.3.3 Abatement

This section presents abatement efficiencies when measures are in place to reduce emissions from storage of coal (see Table 3-7). The resulting emission can be calculated by replacing the technology specific emission factor with an abated emission factor as given in the formula:

$$EF_{technology,abated} = (1 - \eta_{abatement}) \times EF_{technology,unabated} \quad (5)$$

Table 3-7 Abatement efficiencies ($\eta_{abatement}$) for source category 1.B.1.a Coal mining and handling, Coal storage

Tier 2 abatement efficiencies					
	Code	Name			
NFR Source Category	1.B.1.a	Coal mining and handling			
Fuel	NA				
SNAP (if applicable)	050103	Storage of solid fuel			
Technologies/Practices	Storage of coal				
Abatement technology	**Pollutant**	**Efficiency**	**95% confidence interval**		**Reference**
		Default value	**Lower**	**Upper**	
Use of water sprays	PM10	50%	40%	55%	Australian Government (2000)
Use of sprinklers and binding materials	PM10	90%	80%	95%	US EPA (2006)

3.3.4 Activity data

The relevant activity statistics for applying a Tier 2 methodology in the mining and handling of coal is the amount of coal produced from these activities.

For calculating emissions from storage of coal, the relevant activity statistics is the total area that coal is stored on (expressed in ha).

3.4 Tier 3 Emission modelling and use of facility data

A Tier 3 methodology for emission factors estimation for open dust sources at coal mines can be found in the US Environmental Protection Agency (US EPA) AP-42, chapter 11.9, Western surface coal mining) (US EPA, 1998).

A Tier 3 methodology for emission factors estimation for fugitive emissions from coal piles, including emissions from loading, wind erosion, equipment traffic and load out, can be estimated using the formula given in US EPA (2006), applying country specific values for the relevant parameters:

$$E = k(0.0016)\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

E: emission factor (kg/Mg)
k: particle size multiplier
U: mean wind speed (m/s)
M: material moisture content (%)

4 Data quality

4.1 Completeness

No specific issues.

4.2 Avoiding double counting with other sectors

No specific issues.

4.3 Verification

No specific issues.

4.4 Developing a consistent time series and recalculation

No specific issues

4.5 Uncertainty assessment

4.5.1 Emission factor uncertainties

The uncertainty in the emission factors for NMVOC is very high. They are calculated using the methane emission factors and the species profile of the firedamp. The uncertainty in the emission factors of methane is approximately 50 %, while the uncertainty in the firedamp profile is considered to be greater than a factor of 2.

4.5.2 Activity data uncertainties

The uncertainty in the activity statistics is very low, since national data on tonnage of coal produced is generally considered to be very accurate.

4.6 Inventory quality assurance/quality control QA/QC

No specific issues

4.7 Gridding

No specific issues

4.8 Reporting and documentation

No specific issues

5 Glossary

Firedamp	Inflammable gas released during the working of coal mines. In general, methane is considered a safety hazard.

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7 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the Task Force on Emission Inventories and Projection's expert panel on combustion and industry. Please refer to the TFEIP website (www.tfeip-secretariat.org/) for the contact details of the current expert panel leaders.