SCIENTIFIC OPINION

Scientific Opinion on Dietary Reference Values for energy[1]

EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA)[2, 3]

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ABSTRACT

This Opinion of the EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA) deals with the setting of Dietary Reference Values (DRVs) for energy. Only one DRV, the Average Requirement (AR) for energy was set for adults, infants and children, and pregnant and lactating women. For children and adults, total energy expenditure (TEE) was determined factorially from estimates of resting energy expenditure (REE) plus the energy needed for various levels of physical activity (PAL) observed in healthy individuals. To take into account the uncertainties inherent in the prediction of energy expenditure, ranges of the AR for energy were calculated with several predictive equations for REE for children and adults. For practical reasons, only the REE estimated by one equation was used in the setting of the AR. For the estimation of REE in adults, body heights measured in representative national surveys in 13 Member States of the European Union and body masses calculated from heights assuming a body mass index of 22 kg/m^2 were used, whereas for children the medians of reference body masses and heights of children in the European Union were used. In children, energy expenditure for growth was accounted for by a 1 % increase of PAL values for each age group. For infants, the AR was derived from TEE estimated by regression equation based on doubly labelled water data, plus the energy needs for growth. For pregnant and lactating women, the additional energy needed for the deposition of newly formed tissue, and for milk output, was derived from data acquired with the doubly labelled water method, and from factorial estimates, respectively. © European Food Safety Authority, 2012

KEY WORDS

Energy, resting energy expenditure, prediction equation, physical activity level, total energy expenditure, factorial method, average requirement

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SUMMARY

Following a request from the European Commission, the EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA) was asked to deliver a scientific opinion on Population Reference Intakes for the European population, including energy.

Reference values for energy are given as average requirements of specified age and sex groups. Total energy expenditure (TEE) in a steady state of body mass was chosen as the criterion on which to base the average requirement for energy. In practice, the adequacy of usual energy intakes is best monitored by measuring body mass. In terms of regulation of body mass, the overall energy balance over a prolonged period of time needs to be considered.

TEE expended over 24 hours is the sum of basal energy expenditure, the energy expenditure of physical activity and the thermic effect of food. In this Opinion, resting energy expenditure (REE) was used as a proxy for the slightly higher basal energy expenditure, as most studies measured REE.

TEE is best measured with the doubly labelled water method, which provides energy expenditure data over biologically meaningful periods of time and under normal living conditions. One approach to determine the average requirement for energy is to use TEE measured by the doubly labelled water method and to derive regression equations which describe how TEE varies as a function of anthropometric variables (such as body mass and height) for defined population groups and of an activity constant to account for the level of physical activity. However, this approach has been criticised because of the inability of TEE prediction models to account for the variation in energy expenditure of physical activity in a transparent way. In addition, limited TEE data generated with the doubly labelled water method are available, and they may not be representative for the European population; moreover, some age groups are underrepresented. Another approach to estimate TEE is by the factorial method that adds to measured or predicted REE the energy spent in various activities. This is done by using the physical activity level (PAL) which is defined as the 24-hour-ratio of TEE to REE and reflects the part of TEE that is due to physical activity. Accordingly, TEE is predicted as PAL x REE. During growth, pregnancy and lactation, additional energy is needed for the synthesis of new tissues, and for covering the energy deposited as fat or protein in the tissues, or for milk production. In this Opinion, TEE of children and adults was estimated factorially to account for the diversity in body size, body composition and habitual physical activity among children and adult populations with different geographic, cultural and economic backgrounds.

To estimate REE, predictive equations are used that have been derived by regression analysis of measured REE, and of body masses and heights, from groups of subjects. Body mass is the most important determinant of REE and all predictive equations use this parameter. In addition to body mass, height, sex, age and ethnicity affect REE significantly and numerous equations have been developed to take into account one or several of these parameters. Based on the results of various publications on the accuracy of these equations in specified population groups, five widely used equations (Harris and Benedict, 1919; Henry, 2005; Mifflin et al., 1990; Müller et al., 2004; Schofield et al., 1985) can be considered as equally valid for estimating REE of healthy adults in Europe. For healthy children and adolescents in Europe, the equations of Schofield et al. (1985) and Henry (2005) derived from large datasets and covering wide age groups are considered to be the most suitable.

PAL can be estimated either from time-allocated lists of daily activities expressed as physical activity ratio values or, alternatively, from the ratio of TEE (measured by the doubly labelled water method) to REE (either measured or estimated). However, the same limitations apply to the derivation of PAL values from doubly labelled water data as to the estimates of TEE with this method. Within the general population, PALs associated with sustainable lifestyles have been observed to range between 1.35 and 2.5. PAL values decrease only marginally with age. When assigning PAL values to descriptions of activities/lifestyles (such as light, moderate or heavy activity), the range of PAL values in each lifestyle category is large. Thus, the allocation of lifestyles to defined PAL values can be

considered only as a rough indication of PAL, but may be useful for decisions on which PAL values to apply in various circumstances and applications.

In the absence of arguments for the selection of one predictive equation best fitted to adults in the European Union (EU), REE was calculated with five widely applied predictive equations using measured individual data on body heights of adults obtained in 13 representative national surveys in EU Member States with corresponding body masses calculated for a body mass index of 22 kg/m^2. This yielded a range of average requirements calculated for PAL values from 1.4 through 2.4 in steps of 0.2, and demonstrates the magnitude of uncertainty inherent in these values. However, for practical reasons, only one average requirement is proposed for a defined age and sex group with a healthy body mass, and for PAL values selected to approximate corresponding lifestyles. The predictive equations of Henry (2005) were used to estimate REE. To derive TEE as REE x PAL, PAL values of 1.4, 1.6, 1.8 and 2.0 were chosen to reflect low active, moderately active, active and very active lifestyles. Because of a lack of anthropometric data from EU countries for age groups from 80 years onwards, average requirements were not calculated for adults ≥ 80 years.

For infants during the first half year of life (from birth to six months of age) energy requirements were considered to be equal to the supply from human milk, and no estimates of average requirements were proposed in this Opinion. For infants aged 7-11 months, the average requirements for energy were estimated from equations for TEE based on TEE measured by the DLW method in healthy, breast-fed, non-stunted infants born at term with adequate body mass, adding the energy needs for growth. World Health Organisation Growth Standard body masses were used to derive average requirements for infants growing along the trajectory of this standard. Estimates of the energy expenditure for growth were based on protein and fat gains reported in the literature.

The average requirement for energy for children and adolescents is based on predicted REE and PAL adjusted for growth. REE was calculated by entering median reference body masses and heights of children in Europe in the predictive equations of Henry (2005) and Schofield et al. (1985). For practical reasons, and because the results obtained with these two equations were very similar, only the equations of Henry (2005) were applied for the estimation of REE values. PAL values of 1.4, 1.6, 1.8 and 2.0 were used for three age groups (1 to 3 years, >3 to <10 years, and 10 to 18 years). Energy expenditure for growth was accounted for by a 1 % increase of PAL values for each age group.

For pregnant women, a mean gestational increase in body mass of 12 kg has been reported to be associated with optimal maternal and foetal health outcomes. The additional amount of energy required during pregnancy to support this increase in body mass was estimated using the cumulative increment in TEE estimated with the doubly labelled water technique plus the energy deposited as protein and fat. Based on these data, the average additional energy requirement for pregnancy is 320 MJ divided into approximately 0.3 MJ/d, 1.1 MJ/d and 2.1 MJ/d during the first, second and third trimesters, respectively.

For women exclusively breastfeeding during the first six months after birth, the additional energy requirement during lactation was estimated factorially as 2.1 MJ/d over pre-pregnancy requirements, taking into account a requirement of 2.8 MJ/d for milk production and an energy mobilisation from maternal tissues of about 0.72 MJ/d. No additional energy requirement is proposed for women lactating beyond the first six months after birth because volumes of milk produced during this period are highly variable and depend on infants' energy intake from complementary foods.

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BACKGROUND AS PROVIDED BY THE EUROPEAN COMMISSION

The scientific advice on nutrient intakes is important as the basis of Community action in the field of nutrition, for example such advice has in the past been used as the basis of nutrition labelling. The Scientific Committee for Food (SCF) report on nutrient and energy intakes for the European Community dates from 1993. There is a need to review and if necessary to update these earlier recommendations to ensure that the Community action in the area of nutrition is underpinned by the latest scientific advice.

In 1993, the SCF adopted an opinion on nutrient and energy intakes for the European Community[4]. The report provided Reference Intakes for energy, certain macronutrients and micronutrients, but it did not include certain substances of physiological importance, for example dietary fibre.

Since then new scientific data have become available for some of the nutrients, and scientific advisory bodies in many European Union Member States and in the United States have reported on recommended dietary intakes. For a number of nutrients these newly established (national) recommendations differ from the reference intakes in the SCF (1993) report. Although there is considerable consensus between these newly derived (national) recommendations, differing opinions remain on some of the recommendations. Therefore, there is a need to review the existing EU Reference Intakes in the light of new scientific evidence, and taking into account the more recently reported national recommendations. There is also a need to include dietary components that were not covered in the SCF opinion of 1993, such as dietary fibre, and to consider whether it might be appropriate to establish reference intakes for other (essential) substances with a physiological effect.

In this context the EFSA is requested to consider the existing Population Reference Intakes for energy, micro- and macronutrients and certain other dietary components, to review and complete the SCF recommendations, in the light of new evidence, and in addition advise on a Population Reference Intake for dietary fibre.

For communication of nutrition and healthy eating messages to the public it is generally more appropriate to express recommendations for the intake of individual nutrients or substances in food-based terms. In this context the EFSA is asked to provide assistance on the translation of nutrient based recommendations for a healthy diet into food based recommendations intended for the population as a whole.

TERMS OF REFERENCE AS PROVIDED BY THE EUROPEAN COMMISSION

In accordance with Article 29 (1)(a) and Article 31 of Regulation (EC) No. 178/2002, the Commission requests EFSA to review the existing advice of the Scientific Committee for Food on population reference intakes for energy, nutrients and other substances with a nutritional or physiological effect in the context of a balanced diet which, when part of an overall healthy lifestyle, contribute to good health through optimal nutrition.

In the first instance the EFSA is asked to provide advice on energy, macronutrients and dietary fibre. Specifically advice is requested on the following dietary components:

- Carbohydrates, including sugars;
- Fats, including saturated fatty acids, polyunsaturated fatty acids and monounsaturated fatty acids, *trans* fatty acids;
- Protein;

[4] Scientific Committee for Food, Nutrient and energy intakes for the European Community, Reports of the Scientific Committee for Food 31st series, Office for Official Publication of the European Communities, Luxembourg, 1993.

- Dietary fibre.

Following on from the first part of the task, the EFSA is asked to advise on population reference intakes of micronutrients in the diet and, if considered appropriate, other essential substances with a nutritional or physiological effect in the context of a balanced diet which, when part of an overall healthy lifestyle, contribute to good health through optimal nutrition.

Finally, the EFSA is asked to provide guidance on the translation of nutrient based dietary advice into guidance, intended for the European population as a whole, on the contribution of different foods or categories of foods to an overall diet that would help to maintain good health through optimal nutrition (food-based dietary guidelines).

PREAMBLE

In the Opinion on General Principles (EFSA Panel on Dietetic Products Nutrition and Allergies (NDA), 2010), the Panel distinguishes between reference values and recommendations: "Dietary Reference Values are scientific references based on health criteria, taking into account dietary requirements and health outcomes. […] They represent one of the bases for establishing nutrient recommendations and food based dietary guidelines. […] Nutrient goals and recommendations may differ between countries depending on health needs, nutritional status and known patterns of intake of foods and nutrients in specific populations and the actual composition of available foods". In this Opinion, the Panel proposes reference values that need to be adapted to specific objectives and target populations.

In this Opinion on Dietary Reference Values (DRVs) for energy, the Panel decides to introduce the scientifically correct term "body mass" instead of "body weight" which is in accordance with the International System of Units (SI).

ASSESSMENT

1. Introduction

Human beings need energy to perform and regulate all biochemical processes that maintain body structures and functions, and to perform physical activities.

Energy is provided in the diet by carbohydrates, fats, protein and alcohol and the individual contribution of these sources is variable. Thus, DRVs for energy are not specified as defined amounts of a single nutrient but are expressed in units of energy.

DRVs for energy differ from those for nutrients in that (a) there is a wide inter-individual variation in the behavioural, physiologic and metabolic components of energy needs. The energy requirement of a defined group cannot be applied to other groups or individuals who differ from the defined group in sex, age, body mass, activity level and possibly other factors; (b) there are differences between the energy supply needed to maintain current body mass and level of actual physical activity and the energy supply needed to maintain desirable body mass and level of physical activity consistent with good health.

The proposed DRVs for food energy provide a best estimate of the food energy needs of the European population and its subgroups and present criteria against which to judge the adequacy of their food energy intakes. They constitute the basis for policy-makers and authorities to make recommendations for populations which can be used for the development and monitoring of nutrition programmes, for planning agricultural production, food supplies and, as the case may be, the mobilisation and distribution of emergency food aid.

1.1. Definition of energy requirement

Energy requirement is the amount of food energy needed to balance energy expenditure in order to maintain body mass, body composition, and a level of physical activity consistent with long-term good health. This includes the energy needed for the optimal growth and development of children, for the deposition of tissues during pregnancy and for the secretion of milk during lactation consistent with good health of mother and child (FAO/WHO/UNU, 1985, 2004; IoM, 2005; SCF, 1993).

1.1.1. Concept of dietary reference values (DRVs) for energy

Following the definition of energy requirement, dietary reference values are based on estimates of the requirements of healthy individuals, representative for a particular population group. Due to usual biological variability there is a distribution of energy requirements even within such groups. Whereas

DRVs for protein and various micronutrients are given as population reference intakes (PRI)[5], DRVs for energy are provided as average requirements (ARs) of specified groups. Due to the very large variation coefficients (CV) induced by large differences in physical activity levels (PAL) and anthropometric parameters, the definition of a PRI would be inappropriate, since it implies an intake above the requirement for nearly all subjects and would lead to a positive energy balance and promote an unfavourable increase in body mass and the development of obesity in the long term. The AR for energy as a reference value exceeds the requirement of half of the individuals of any specified group. The AR for energy relates to groups of healthy people and is of limited use for individuals.

The AR for energy is expressed on a daily basis but represents an average of energy needs assessed over a minimum of a week.

In accordance with the International System of Units, the FAO/WHO/UNU consensus (1971) and the European regulations[6], the AR for energy will be expressed in Joules (J); in addition, because of the continuing use of thermochemical energy units (calories, cal), equivalents[7] will be given in brackets or in separate tables in the Appendix.

1.1.2. Approach

The AR for energy can be established by two approaches: either by measurements of energy intake or by measurements of energy expenditure of healthy reference populations. Because the day-to-day variation in energy intake is considerably larger than the day-to-day variation in total energy expenditure (TEE) in a steady state of body mass, measurements or estimates of TEE have been chosen by experts from FAO/WHO/UNU (1985, 2004) and the US Institute of Medicine (IoM, 2005) as the criterion on which to base the AR for energy. The Panel agrees with this approach.

2. Definition/Category

2.1. Components of total energy expenditure (TEE)

Total energy expenditure (TEE) expended over 24 hours is the sum of basal energy expenditure (BEE), the energy expenditure of physical activity (EEPA), the thermic effect of food (TEF) and in less frequent situations cold-induced thermogenesis.

2.1.1. Basal energy expenditure (BEE)

Basal energy expenditure (BEE) is the energy used to maintain the basic physiological functions of the body at rest under strictly defined conditions: after an overnight fast corresponding to 12-14 hours of food deprivation, awake, supine, resting comfortably, motionless, no strenuous exercise in the preceding day (or eight hours of physical rest), being in a state of “mental relaxation” and in a thermoneutral environment. BEE is the main component (45-70 %) of TEE (FAO/WHO/UNU, 2004).

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[5] The PRI is defined as the level of intake that is adequate for virtually all people in a population group, which is determined as the average requirement (AR) of the population group plus two standard deviations (EFSA Panel on Dietetic Products Nutrition and Allergies (NDA), 2010. Scientific Opinion on principles for deriving and applying Dietary Reference Values. EFSA Journal, 8(3):1458, 30 pp.)

[6] Council Directive 90/496/EEC of 24 September 1990 on nutrition labelling for foodstuffs. OJ L 276, 6.10.1990, p. 40–44. Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers, amending Regulations (EC) No 1924/2006 and (EC) No 1925/2006 of the European Parliament and of the Council, and repealing Commission Directive 87/250/EEC, Council Directive 90/496/EEC, Commission Directive 1999/10/EC, Directive 2000/13/EC of the European Parliament and of the Council, Commission Directives 2002/67/EC and 2008/5/EC and Commission Regulation (EC) No 608/200. OJ L 304, 22.11.2011, p. 18–63.

[7] 1 joule (J) is the amount of mechanical energy required to displace a mass of 1 kg through a distance of 1 m with an acceleration of 1 m per second (1 J=1 kg×1 m^2×1 sec^{-2}). Multiples of 1,000 (kilojoules, kJ) or 1 million (megajoules, MJ) are used in human nutrition. The conversion factors between joules and calories are: 1 kcal=4.184 kJ, or conversely, 1 kJ=0.239 kcal.

2.1.2. Resting energy expenditure (REE)

By definition, resting energy expenditure (REE) is the energy expended when the body is at rest, which is when no extra energy is spent for muscular effort. In many studies, for practical reasons since conditions for measuring BEE are more stringent, REE instead of BEE is measured. Changes in REE are used to measure the expenditure of many processes such as thermoregulation, eating, and excess post-exercise oxygen consumption. Practically, REE is measured in conditions less stringent than the ones that prevail for measurement of BEE, so that REE is usually slightly higher than BEE (up to 10 %). In this Opinion REE is used as a proxy for BEE, as most studies measure REE.

2.1.3. Sleeping energy expenditure (SEE)

Sleeping energy expenditure (SEE) can be measured instead of BEE or REE to estimate daily energy requirements. SEE is usually considered to be lower than REE depending on the sleeping phase (Wouters-Adriaens and Westerterp, 2006). SEE can be considered as a practical means to approach BEE particularly in infants for whom the criteria related to measurements of BEE would be impractical.

2.1.4. Cold-induced thermogenesis

Cold-induced thermogenesis is the production of heat in response to environmental temperatures below thermoneutrality. Cold-induced thermogenesis can be divided into two types: shivering thermogenesis and non-shivering thermogenesis. The thermoneutral zone (or the critical temperature) is the environmental temperature at which oxygen consumption and metabolic rate are lowest (IoM, 2005). The relative contribution of cold-induced thermogenesis to TEE has decreased in recent decades due to the increase in time spent in enclosed and heated environments.

2.1.5. Thermic effect of food (TEF)

Eating requires energy for the digestion, absorption, transport, interconversion, and deposition of nutrients. These metabolic processes increase REE, and their energy expenditure is known as the thermic effect of food (TEF). It should be noted that the muscular work required for eating is not part of TEF.

2.1.6. Energy expenditure of physical activity (EEPA)

Physical activity can be defined as any body movement produced by skeletal muscles which results in energy expenditure. In practice, physical activity in daily life can be categorised into obligatory and discretionary activity. The term “obligatory” is more comprehensive than the term “occupational” that was used in the 1985 report (FAO/WHO/UNU, 1985) because, in addition to occupational work, obligatory activities include daily activities such as going to school, tending to the home and family and other demands made on children and adults by their economic, social and cultural environment (FAO/WHO/UNU, 2004). Levine (2004b) has divided the energy expended during physical activity into exercise activity thermogenesis and non-exercise activity thermogenesis (NEAT). Exercise activity thermogenesis is the energy expended during voluntary exercise (discretionary) which is a type of physical activity that is planned, structured, and repetitive. NEAT is the energy expenditure of all physical activities other than sleeping, eating or sports-like exercise. It includes the energy expended during daily activities such as working, walking, doing housework, gardening, etc., and fidgeting, which corresponds to small unconscious muscle movements (Levine, 2004b).

The physical activity level (PAL) is defined as the 24-hour-ratio of TEE to REE. It reflects the part of TEE that is due to physical activity. The physical activity ratio (PAR) is used to express the increase in energy expenditure per unit of time induced by a given activity and can also be expressed as a multiple of REE.

2.1.7. Adaptive thermogenesis

Adaptive thermogenesis is defined as the heat that can be added or not from the normal thermogenic response to food and/or cold in order to best adjust energy expenditure to the requirements of energy balance (Wijers et al., 2009). Several studies conducted in recent years suggest that mitochondrial uncoupling protein in brown adipose tissue (Nedergaard et al., 2007) and skeletal muscle tissue in adult humans can be the main effectors of adaptive thermogenesis. Other mechanisms such as futile calcium cycling, protein turnover and substrate cycling may be involved (Harper et al., 2008). Under normal circumstances in healthy individuals, adaptive thermogenesis does not account for a significant component of TEE.

2.2. Methods of assessing energy expenditure and its components

2.2.1. General principles

2.2.1.1. Direct calorimetry

As body temperature is maintained constant, the energy expended by the body has to be dissipated as heat. Direct calorimetry measures the heat released by the subject by conduction, convection and evaporation. Direct calorimetry has been used in the past to validate the principle of indirect calorimetry but is less used presently because of its cost and complexity (Seale et al., 1991; Walsberg and Hoffman, 2005).

2.2.1.2. Indirect calorimetry

Indirect calorimetry is based on the principle that energy production by substrate oxidation in the body is coupled to oxygen consumption (VO_2) and carbon dioxide production (VCO_2) and has become the reference method to measure energy expenditure. Many equations have been derived to provide an exact measure of energy expenditure from VO_2 and VCO_2 (Brouwer, 1957; Elia, 1992; Lusk, 1928; Weir, 1949; Zuntz, 1897). The most widely used is the Weir formula; the other formulas give results that all lie within ± 1 % of the results by Weir (1949).

Closed-circuit indirect calorimetry: At a time when no accurate automated gas analysers were available, the closed-circuit system allowed a volumetric measurement of VO_2 to be performed. In the closed-circuit design, VCO_2 is absorbed within the system, and VO_2 is measured either from the decrease in the volume of gas in the system, or by the amount of oxygen required to maintain the pressure in the chamber. Closed-circuit systems are no longer used for measurement of REE in humans.

Open-circuit indirect calorimetry: The principle of the open-circuit device is that the respiratory gases of the subject are collected in a device ventilated at a known flow-rate, and VO_2 and VCO_2 are computed by multiplying the changes in % O_2 and % CO_2 in the container by the air flow. Various open-circuit systems have been designed based on this principle. Ventilated open-circuit systems such as ventilated hood, canopy, and whole room calorimeters are most used for assessing BEE, REE, TEF and TEE. Expiratory collection systems are systems where the subject inspires from the atmosphere and expires via a non-return valve into a measurement unit. They are mostly used for exercise and field measurements via portable systems. Open-circuit indirect calorimeters are reliable and have an error of 0.5–2 % (Compher et al., 2006; Schoeller, 2007; Wahrlich et al., 2006).

A main advantage of the open-circuit devices is that, since both VCO_2 and VO_2 are measured, it is possible to compute VCO_2 over VO_2 which is defined as the respiratory quotient (RQ). RQ values vary depending on the substrate mixture oxidised (0.7 for lipids, 0.82 for proteins and 1.0 for glucose). A precise computation of the respective levels of glucose, lipids and protein oxidation thus requires that protein oxidation be measured. This is usually done by measuring urinary nitrogen excretion assuming that, on average, nitrogen excreted multiplied by 6.25 is equivalent to the amount of protein oxidised (EFSA Panel on Dietetic Products Nutrition and Allergies (NDA), 2012).

2.2.1.3. Doubly labelled water (DLW) method

The doubly labelled water (DLW) method is used for determining TEE in free-living subjects. It is based on the disappearance rates in body fluids (usually urine sampled at three or more intervals) of two orally administered stable isotopes of water ($H_2{}^{18}O$ and ${}^{2}H_2O$) during the 15 following days (which corresponds to about two biological half-lives of the isotopes) (Schoeller, 1988). VCO_2 is calculated from the difference between the disappearance rates of ${}^{18}O$ and ${}^{2}H$. VO_2 is calculated from VCO_2 by estimating the RQ from the food quotient (FQ; sum of RQ of individual foods/energy contribution in 24 hours) of either the reported macronutrient intake of the subject or average data from population surveys. TEE can then be calculated from the energy equivalent of VCO_2 for the given diet (Elia, 1991) or from VCO_2 measured and VO_2 calculated with the use of the FQ using the same standard equations as for indirect calorimetry. Computation of TEE with DLW relies on a series of assumptions including the constancy of the water pool throughout the measurement period, the rate of H_2O and CO_2 fluxes, the isotopic fractionation, and no label-re-entering the body (IDECG, 1990). The reproducibility and accuracy of the DLW technique may vary markedly among analytical centres, and estimates of ± 8.5 % for the reliability of TEE have been reported (Goran et al., 1994b). The main advantages of DLW versus calorimetry are that (i) it provides energy expenditure estimations over biologically meaningful periods of time, (ii) it captures energy expenditure of all kinds of activities including spontaneous movements and fidgeting, and (iii) being non-invasive, measurements can be made in subjects leading their usual daily lives.

2.2.1.4. Heart rate (HR) monitoring

Heart rate (HR) monitoring can be used to estimate TEE but individual calibrations of the relationship between HR and oxygen consumption must be performed because the relationship between HR and TEE varies between subjects (Bitar et al., 1996; Ceesay et al., 1989).

2.2.2. Basal and resting energy expenditure (BEE and REE)

BEE and REE as a proxy for BEE are best determined by indirect calorimetry measurements under standardised laboratory conditions (Compher et al., 2006; Harris and Benedict, 1919).

2.2.3. Thermic effect of food (TEF)

TEF is best measured in laboratory conditions from changes in REE induced by ingestion of a standardised meal of known composition and of 1,700 kJ (~400 kcal) or greater. In practice, first REE is measured (see Section 2.1.2.), then the meal is ingested, and the meal-induced increase in REE versus the pre-meal value is measured.

2.2.4. Energy expenditure of physical activity (EEPA)

As for TEF, energy expenditure of physical activity (EEPA) should be measured relative to REE or relative to the energy expenditure of the reference activity (e.g. expenditure of office work relative to energy expenditure while seated, expenditure of walking or running relative to energy expenditure while standing).

The measurement of average daily TEE by the DLW method combined with a measurement of REE permits the calculation of the energy expenditure for the average physical activity of an individual (Westerterp and Goran, 1997) but does not provide information on the expenditure and time spent in the various activities. Energy expenditure of fidgeting has been assessed with indirect calorimetry measurements as the difference in energy expenditure at rest and various levels of activities with and without fidgeting (Levine et al., 2000). At a population level, systematic data on the amount and expenditure of NEAT are scarce.

Tables have been developed which ascribe to each type of activity a physical activity ratio (PAR) that defines the energy expended while performing this activity relative to REE (e.g. FAO/WHO/UNU, 2005). Such tables are of limited value because of inconsistencies in the way the data were collected and presented, and because of differences in the description of activities, computation/prediction of

REE and conditions of measurements (Vaz et al., 2005). As a result, PAR values of a given activity can vary highly across studies.

2.2.5. Total energy expenditure (TEE)

TEE in normal living conditions is best estimated with the DLW method (Coward and Cole, 1991) that allows long-term measurements and better preserves normal behaviour than recording in room calorimeters, but it is an expensive method. Therefore, TEE in a population group is generally estimated by factorial methods that add to measured or calculated REE the energy spent in various activities.

The factorial method is based on the calculation of TEE from a record of the activities (type and duration) in free-living conditions and the energy expenditure of each activity reported in compilation tables and REE. The factorial method thus requires (i) accurate recording of daily activities, which is tedious (especially for children), (ii) accurate data on the energy expenditure of most individual daily activities and (iii) a precise value for REE, either measured or calculated from either body mass, body mass and body height, or body composition. The difficulty of complying with all three requirements is a source of large potential errors at the individual level, but the factorial method can be applied to estimate TEE in groups of people.

2.2.6. Energy expenditure for growth

The increase in energy expenditure induced by growth results from the expenditure for protein and lipid synthesis and their deposition in newly formed tissue. It is significant only in rapidly growing infants and children. It cannot be measured by indirect calorimetry or the DLW method because there is no means to have access to a reference “growth-free” REE. However, it can be evaluated from changes in body composition measured in groups of healthy growing infants (Torun, 2005). A factorial method which consists of measuring changes in body composition and estimating the energy requirements from the estimated energetic efficiencies of the biochemical pathways involved in protein and lipid synthesis can also be used (Butte, 2005).

2.2.7. Energy expenditure of pregnancy

Energy expenditure related to pregnancy is calculated using two different approaches. Both require that measurements be started before conception, which raises difficulties associated with recruiting women likely to become pregnant in the near future. The first approach is based on serial measurements of REE assuming that EEPA and TEF are not affected by pregnancy(Prentice et al., 1996a). In the second approach, calculations can be based on serial measurements of TEE using the DLW method. This method not only includes the energy expenditure for tissue deposition but also any changes in TEF and EEPA.

2.2.8. Energy expenditure of lactation

Energy expenditure for lactation can be computed from the amount of milk produced, the energy content of the milk, and the energetic efficiency of milk synthesis. The efficiency of converting dietary energy into human milk has been estimated from theoretical biochemical efficiencies of synthesising the constituents in milk, and from metabolic balance studies (Prentice and Prentice, 1988). Biochemical efficiency can be calculated from the stoichiometric equations and the obligatory heat losses associated with the synthesis of lactose and protein, and fat. When the expenditure for digestion, absorption, inter-conversion and transport is taken into account, the estimate of efficiency of milk synthesis yields a figure of 80–85 % (Butte and King, 2005).

2.3. Determinants of energy expenditure

2.3.1. Body mass and body composition

The relationship of body mass and body composition to energy expenditure is not appropriately reflected in the simple regression of REE and body mass, which does not regress through the zero intercept and is not linear, because body composition does not evolve linearly with body mass (Müller et al., 2002). The various tissues and organs of the body have very different mass-specific metabolic rates, with very low or null values for plasma, collagen, tendons, fluids and bones, for example, low values for adipose tissues, average values for muscles and high values for brain, heart, liver and kidneys (Elia, 1992; Müller et al., 2002; Wang et al., 2010). Thus, the contribution of fat mass (FM) to energy expenditure is low in lean subjects, but cannot be neglected in overweight and obese subjects (Müller et al., 2004; Prentice et al., 1996b; Schulz and Schoeller, 1994). In addition, it has been demonstrated that fat distribution is a key determinant for the contribution of body fat to REE. For example, abdominal fat has a greater metabolic activity than peripheral fat (Lührmann et al., 2001). Prediction of REE can be improved by using multicomponent body composition models based on various techniques. This may be particularly useful in populations for which the current equations may not properly predict REE (Wilms et al., 2010), and for reassessing the validity of ethnic and sex differences.

2.3.2. Physical activity

EEPA is the most variable component of TEE, both within and between subjects, ranging from 15 % of TEE in very sedentary individuals to 50 % or more of TEE in highly active individuals. The energy expended with exercise is often negligible or zero in individuals, but even in those who exercise regularly, the energy expended with NEAT is far larger than the energy expended with exercise. Thus, energy requirements related to physical activity mainly arise from NEAT. NEAT can vary between two people of similar size by more than 8 MJ/d (1,912 kcal/d) because of different occupations, leisure-time activities and fidgeting. Fidgeting can increase daily energy expenditure above REE levels by 20–40 % (Levine et al., 2000) and has been related to long-term control of body mass (Levine and Kotz, 2005).

The energy expended with physical activity also depends on the energetic efficiency with which activities are performed, and these also vary between individuals. In general, the energy expenditure of body mass bearing activities (walking, running) increases with body mass (Bray et al., 1977; Levine, 2004a), but, when expressed on a per kilogram basis, the energy expended to walk a fixed distance or at a given speed can be as much as two to three times greater for smaller than for larger individuals (Weyand et al., 2010).

2.3.3. Growth

Growth increases energy expenditure through expenditure for synthesising new tissues. However, except for the first months of life, the energy requirement for growth relative to the total energy requirement is small; it decreases from about 40 % at age one month to about 3 % at the age of 12 months (Butte, 2005).

2.3.4. Pregnancy

The effect of pregnancy on energy expenditure varies during the course of pregnancy and differs considerably between individual women. Pregnancy increases REE due to the metabolic contribution of the uterus and foetus to the expenditure of tissue deposition, and to the increased work of the heart and lungs (Forsum and Löf, 2007; Hytten and Chamberlain, 1980). Pregnancy can also affect EEPA.

It is primarily related to the increased energy needed for tissue maintenance of the increased tissue mass. For REE, an average cumulative increment of 147.8 MJ (35,130 kcal) for a gain in body mass of 12 kg was estimated from studies of well-nourished women who gave birth to infants with adequate body masses (Cikrikci et al., 1999; de Groot et al., 1994; Durnin et al., 1987; Forsum et al., 1988; Goldberg et al., 1993; Kopp-Hoolihan et al., 1999; Piers et al., 1995; Spaaij et al., 1994b; van Raaij et al., 1987). Corresponding cumulative average increases in REE have been observed to be around 5 %, 10 % and 25 % in the first, second and third trimesters, respectively. However, even within populations of well nourished women, large variations in the effect of pregnancy on REE are observed (Prentice et al., 1989).

Reviews of numerous studies in a variety of countries indicate that there is little evidence that women are less active during pregnancy (IoM, 1992; Prentice et al., 1996a), although these studies do not give information about changes in the intensity of the effort associated with habitual tasks. Compared with non-pregnant values, the energy expended for EEPA in the third trimester of pregnancy ranged from a decrease of 22 % to an increase of 17 %, but on average did not differ significantly from non-pregnant women (Butte and King, 2002). However, when expressed per unit of body mass, there was a tendency towards lower EEPA/kg per day. Three recent studies in healthy well nourished women reviewed by Forsum and Löf (2007) also concluded that EEPA is not significantly increased during pregnancy. TEF, when expressed in proportion of energy intake, is generally assumed to remain unchanged during pregnancy (Butte and King, 2005; Forsum and Löf, 2007; Kopp-Hoolihan et al., 1999; Prentice et al., 1996a) but considerable intra-individual variations do occur.

2.3.5. Lactation

The main factors that influence the impact of lactation on energy expenditure are the intensity and duration of (exclusive) breastfeeding; this may vary widely between individuals and populations. In exclusively breastfeeding women, the mean amount of breastmilk produced daily was reported to amount from 562 up to 854 g/d during the first 6 months *post partum* (Butte et al., 2002; FAO/WHO/UNU, 2004) with an average gross energy content of 2.8 kJ/g (0.67 kcal/g) (Butte and King, 2002; FAO/WHO/UNU, 2004; Garza and Butte, 1986; Goldberg et al., 1991; IoM, 1991; Panter-Brick, 1993; Prentice and Prentice, 1988; WHO, 1985).

Increases in REE of 4 to 5 % have been observed in lactating women (Butte et al., 1999; Forsum et al., 1992; IoM, 2005; Sadurskis et al., 1988; Spaaij et al., 1994a) which is consistent with the additional energy cost of milk synthesis (IoM, 2005). However, others have reported similar REE in lactating women compared to the non-lactating state (Frigerio et al., 1991; Goldberg et al., 1991; Illingworth et al., 1986; Motil et al., 1990; Piers et al., 1995; van Raaij et al., 1991). Thus, during lactation there seem to be no significant changes in REE compared with non-pregnant, non-lactating women; furthermore, there also seem to be no significant changes in the efficiency of work perfomance or TEE (FAO/WHO/UNU, 2004; IoM, 2005).

2.3.6. Endocrinological factors

Several hormones, such as the thyroid hormone (al-Adsani et al., 1997; Danforth and Burger, 1984; Silva, 2006), glucagon or epinephrine (Heppner et al., 2010), glucocorticoids (Silva, 2006), insulin, leptin (Belgardt and Bruning, 2010), estrogens and progesterone (Bisdee et al., 1989; Webb, 1986) are implicated in the regulation of energy expenditure but their impact on the energy expenditure of healthy subjects is generally considered as minute.

2.3.7. Ageing

There is no clear evidence for a decrease in organ metabolic rate, i.e. per g of tissue mass, in healthy ageing (Gallagher et al., 1996; Gallagher et al., 2000). There is also no consistent evidence that TEF changes with ageing. If differences exist they are assumed to be too small to significantly affect energy requirements (Roberts and Dallal, 2005; Roberts and Rosenberg, 2006). Thus, assuming that REE corrected for body composition does not change in older adults but that sarcopenia and increased adiposity decrease the metabolically active mass, and considering the fact that EEPA decreases with ageing (Vaughan et al., 1991), the energy requirement in older adults is generally lower.

2.3.8. Diet

It has been hypothesized that when long-term energy intake surpasses energy expenditure a facultative component generated by stimulation of the sympathetic nervous system and heat dissipation in the brown adipose tissue can add to the obligatory TEF (see Section 2.2.3) to increase TEE. This phenomenon called "Luxuskonsumption" or diet-induced thermogenesis (DIT) was suspected primarily in laboratory rodents (Stock and Rothwell, 1981). The discovery that significant depots of brown fat exist in humans has reactivated the hypothesis that DIT exists in humans and thus that excess dietary intake can increase TEE in humans (Schutz et al., 1984; Wijers et al., 2009). However, the relevance of DIT and the role of the brown adipose tissue as an effector of energy balance has been challenged from the very beginning in rodents (Hervey and Tobin, 1983) and is now contested in humans (Kozak, 2010).

2.3.9. Sex

In general, absolute REE and in consequence TEE is higher in men than in women; these sex-specific differences are mainly due to differences in body mass and body composition (Buchholz et al., 2001; Klausen et al., 1997). There seem to be no significant differences in PAL values between men and women (Roberts and Dallal, 2005).

2.3.10. Ethnicity

Differences in REE have been reported between groups of different ethnic background (e.g. Africans, Asians and Caucasians) and specific predictive equations for REE have been developed more recently to take such differences into account (Vander Weg et al., 2004) (see also Section 2.4.). However, these differences in REE in relation to ethnicity are more the consequences of differences in body mass and composition than related to specific ethnic differences in metabolism (Gallagher et al., 2006; Hunter et al., 2000; Wang et al., 2010).

2.3.11. Environmental factors

Temperature is the main environmental factor that can affect energy expenditure. Humans regulate their body temperature within narrow limits (Danforth and Burger, 1984). This process of thermoregulation can elicit increases in energy expenditure when ambient temperature decreases below the zone of thermoneutrality (Valencia et al., 1992). However, because most people adjust their clothing and environment to maintain comfort, and thus thermoneutrality, the additional energy expenditure of thermoregulation rarely affects TEE to an appreciable extent.

2.4. Equations to predict resting energy expenditure (REE)

Predictive equations are used in practice to predict an individual's REE instead of directly measuring it. Multiplication of REE with a predetermined factor for physical activity will give TEE and energy needs. An accurate prediction of REE is a prerequisite for getting an accurate prediction of TEE.

2.4.1. Predictive equations for adults

Equations for predicting REE are historically based on easily measurable parameters such as body mass, height, sex, age and also ethnicity (see Appendix 1). Basically, these equations are derived by regression analysis of the data from a group of subjects whose REE is measured by direct or indirect calorimetry. The accuracy of an equation is usually estimated as the percentage of subjects that have an REE predicted by the equation within 10 % of the measured REE (Frankenfield et al., 2005). The mean percentage difference between the REE predicted and that measured is considered a measure of accuracy at a population group level.

Body mass is the most important determinant of REE and all predictive equations use this parameter. In addition to body mass, body height, body composition, sex, age and ethnicity can affect REE significantly. Numerous equations have been developed and are still under development to take into account one or several of these parameters. The first set of equations was proposed as early as 1919 (Harris and Benedict, 1919) and has been one of the equations most in use (Daly et al., 1985; FAO/WHO/UNU, 1985, 2004; Schofield et al., 1985). Many new equations have been proposed since then (see Appendix 1). Among these, the equations developed by Owen et al. (1986; 1987), Mifflin et al. (1990), Schofield et al. (1985), Müller et al. (2004), and Henry (2005) are the most popular. The multitude of new equations, their growing complexity, the fact that many equations have been developed for specific categories of people, in particular overweight and obese subjects (Weijs, 2008), and the continuous use of the historical Harris-Benedict equation illustrate a persistent problem: none of these equations is really satisfactory in the sense that, when applied to a group other than the one from which it was derived, significant differences between measured and predicted values can be observed. Thus, the predictive value of equations can vary substantially according to sex, BMI (which reflects body composition), age and ethnicity of the subjects (Hasson et al., 2011).

In 1985, the two most frequently used equations were the Harris-Benedict and the Schofield equations. They have been suspected to overestimate REE. The Harris-Benedict database included a relatively small number of subjects with no children or adolescents below the age of 15 years and a significant number of measurements were obtained by the use of closed-circuit indirect calorimetry whilst the Schofield database included a large number (~40 %) of physically very active (Italian) subjects.

The main studies that reassessed the historical equations and generated new equations are as follows: Owen et al. (1986; 1987) reported that the Harris-Benedict equation overestimated REE by 12.8 % in women and by 6.4 % in men and proposed a new set of equations. Mifflin et al. (1990) observed that the Harris-Benedict equation overestimated REE by 5 % in a group of 498 healthy men and women and developed new predictive equations that are now considered to be among the most relevant and extensively used equations. They also observed that the Owen equations predicted values very close to the REE measured in their study (-4 % in women and 0.1 % in men). Müller et al. (2004) investigated the application of the FAO/WHO/UNU equations (1985) and concluded that the prediction of REE by FAO/WHO/UNU formulas systematically over- and underestimated REE and proposed alternative equations, some of which include the use of the BMI. Finally, Henry (2005) also developed a new database including 5,794 males and 4,702 females from 166 studies (the Oxford database) that excluded the very active (Italian) subjects of the Schofield database and included more individuals from the tropics (n=4,018). In general, the equations proposed by Henry (2005) (Oxford equations) predict lower REE values than the current FAO/WHO/UNU equations in 18–30 and 30–60 year-old men, and in all women over 18 years of age.

Despite the development of numerous new equations intended to improve the predictive power of the Harris-Benedict and Schofield equations, the FAO/WHO/UNU consultation in 2001 (FAO/WHO/UNU, 2004), after re-analysis of the data and attempts to define new equations (Cole, 2002; Henry, 2001), decided to keep the equations proposed by Schofield and colleagues in 1985 that formed the basis for the equations used by FAO/WHO/UNU in 1985. Analysis of the literature published between 2005 and 2011 in which the Harris-Benedict, Schofield or FAO/WHO/UNU equations were tested and compared (among others) to the more recent Owen, Mifflin, Müller and/or Henry equations show that the conclusions can be very different between studies and suggest that the more recent equations do not predict better than the 1919 Harris-Benedict or the present FAO/WHO/UNU equations (Amirkalali et al., 2008; Boullata et al., 2007; Frankenfield et al., 2005; Hasson et al., 2011; Khalaj-Hedayati et al., 2009; Melzer et al., 2007; Weijs et al., 2008; Weijs, 2008; Weijs and Vansant, 2010). Considering the discrepancies in the results of the various publications, there is no reason to favour one set of predictive equation over another and the Panel concludes that the equations by Harris-Benedict (1919), Schofield et al. (1985), Mifflin et al. (1990), Müller et al. (2004) and Henry (2005) can be considered as equally valid, whereas the equations by Owen et al. (1986; 1987) are not proposed because of the large BMI range and the very low number of subjects on which they were based.

<u>Overweight and obese subjects:</u> Recently, Weijs (2008) compared the predictive power of 27 published equations in relation to the origin (USA versus the Netherlands) and the BMI of the subjects. Using three validation criteria, Weijs reported that the Mifflin equation predicted best for overweight (BMI 25-30) and class I and class II (BMI 30-40) obese US adults, but not for the taller Dutch subjects for which there was no single accurate equation.

<u>Ethnicity/environment:</u> Studies have reported lower levels of REE in African-American compared to European-American women (Gannon et al., 2000; Sharp et al., 2002; Weyer et al., 1999). Equations that fail to consider ethnicity may result in inappropriate reference values. In women of African and European origin, Vander Weg et al. (2004) showed that the Owen equation predicted REE best in African-American women but underestimated it in European-American women, whereas the Mifflin

equation predicted best in European-American women. They proposed a new equation including an ethnicity correction factor. As suggested by Müller et al. (2004), Henry (2005) and Frankenfield et al. (2005), the Harris-Benedict and Schofield equations over-predict REE, and more so in women of African rather than European origin. Recently, Yang (2010) showed that the Harris-Benedict, Schofield and Henry equations overpredict REE in Chinese healthy adults, and Nhung (2005) showed that the FAO/WHO/UNU equations overpredicted in Vietnamese adults. Studies on other racial or ethnic groups also demonstrated differences in REE (Benedict, 1932; Henry and Rees, 1991).

2.4.2. Predictive equations for children

For children and adolescents several equations based on age, body mass, height and sex are available to predict REE, among them those of Schofield et al. (1985), Maffeis et al. (1993), Molnar et al. (1995), Müller et al. (2004) and Henry (2005). Predictive equations solely derived from overweight/obese cohorts of children are not considered here. The equations of Schofield were the mostly used in the past and have been cross-validated in various settings. While some studies have suggested that the Schofield equations provide inadequate estimates for infants (Duro et al., 2002; Thomson et al., 1995) and obese adolescents (Hofsteenge et al., 2010), they showed the best agreement with actual measurements in other studies which compared predicted to actual measurements (Firouzbakhsh et al., 1993; Rodriguez et al., 2002). Both the Schofield and the Henry equations were derived from large datasets covering the age groups from 0 to 18 years, whereas the equations of Maffeis et al. (1993), Molnar et al. (1995), and Müller et al. (2004) were developed from smaller samples not including all age groups (see Table 1). The Panel concludes that the equations of Schofield and Henry are equally valid for predicting REE in children with a wide age range.

Table 1: Number of male (m) and female (f) children in the data sets from which the prediction equations for children and adolescents were derived

Age (years)	Harris and Benedict (1919)	Schofield et al. (1985)	Maffeis et. al. (1993)	Molnar et al. (1995)	Müller et al. (2004)	Henry (2005)
< 3		162 m 137 f				277 m 215 f
3-10		338 m 413 f	6-10 y: 62 m 68 f		5-11 y: 99 m 89 f	289 m 403 f
10-18	Only few subjects aged 15 y and older	734 m 575 f		10-16 y: 193 m 178 f	12-17 y: 28 m 27 f	863 m 1063 f

3. Dietary sources of energy and intake data

3.1. Dietary sources of energy

The energy available for metabolism – physiologically available energy – is primarily determined by the chemical energy of the food, which is measured in the laboratory as the heat produced when its organic molecules are fully oxidised. The energy content of food as measured by complete combustion is termed gross energy (GE) or ingested energy (IE). Not all chemical energy in foods is available to humans and the chemical energy value must therefore be corrected for losses due to incomplete digestion and absorption and, as regards protein, for incomplete oxidation and losses as urea (FAO, 2003). The term metabolisable energy (ME) encompasses the energy available after accounting for losses of the ingested energy in faeces, urine, gases from fermentation in the large intestine, and waste products lost from surface areas. Not all ME is available for the production of ATP. When energy losses like the heat of microbial fermentation and obligatory thermogenesis are subtracted from ME, the result is an expression of the energy content of food that will be available to the body for ATP production, which is referred to as net metabolisable energy (NME) (FAO, 2003). In European Union

(EU) legislation, the energy conversion factors for nutrients have been calculated as ME for labelling purposes. The standardised energy conversion factors are given in the Council Directive on nutrition labelling for foodstuffs[8].

The energy carriers in food are carbohydrates, fats, proteins and alcohol. The digestibility and absorption of the respective nutrients, and the heat of combustion, differ depending on the composition and on the foods in which they are found. Correspondingly, energy conversion factors may vary considerably. Specific factors for calculating energy content in certain foodstuffs have been presented (FAO, 2003; Livesey et al., 1995).

<u>Carbohydrate and fibre:</u> The energy conversion factor for carbohydrate presented in food composition tables is in many cases determined by the 'difference method', which defines total carbohydrate as the difference between the total dry matter and the sum of protein, fat and ash, and has a general value of 17 kJ/d (4 kcal/g). The energy conversion factor can also be expressed as monosaccharide equivalents (FAO, 2003). The GE for carbohydrates depends on their composition and number of glycosidic linkages, and ranges from 15.6 to 18 kJ/g (Elia and Cummings, 2007). The energy conversion factor ranges from 16 kJ/g (3.75 kcal/g) to 17 kJ/g (4.0 kcal/g) for available mono- and disaccharides (glucose, galactose, fructose, sucrose) and starch and glycogen, respectively (FAO, 2003). The GE of fibre that reaches the colon does not differ substantially from that of starch and glycogen, but due to large differences in fermentability of fibres in the colon the energy contribution from fibre is less than for other carbohydrates. With the assumption that an average of 70 % of the fibre reaching the colon is fermented, the energy conversion factor for fibre is 8 kJ/g (2 kcal/g) (Elia and Cummings, 2007; FAO, 2003).

<u>Protein:</u> Protein is not fully oxidised in the body. The physiologically available energy from protein is therefore reduced due to both incomplete digestibility and urea losses in the urine. The digestibility of protein is lowest in legumes (78 % of GE) and highest in animal products (97 % of GE). Protein in food may be measured as the sum of individual amino acid residues. In case such values for protein are not available, determination of protein based on total nitrogen by Kjeldahl (or a comparable method) multiplied by a factor is generally accepted. Based on the different amino acid compositions of various proteins, the nitrogen content of proteins varies from about 13 to 19 %. This would equate to nitrogen conversion factors ranging from 5.26 to 7.69. As the average nitrogen content of proteins is about 16 %, the general factor of 6.25 to convert nitrogen content to (crude) protein content is used. When protein is determined in this way, the general energy conversion factor of 17 kJ/g (4 kcal/g) should be applied (FAO, 2003; Merrill and Watt, 1973).

<u>Fat:</u> The GE of fat depends on the fatty acid composition of the triglycerides and the proportion of other lipids in the diet. On average, the ME from fat is calculated as 95 % of GE in most foodstuffs. Fats may be analysed as fatty acids and expressed as triglycerides. For dietary fats, a general energy conversion factor of 37 kJ/g (9 kcal/g) is used (FAO, 2003; Merrill and Watt, 1973).

<u>Alcohol:</u> Although consumption of alcohol can contribute to the hepatic *de novo* lipogenesis pathway, about 80 % of the energy liberated contributes to ATP production (Prentice, 1995; Raben et al., 2003). Ethanol is promptly oxidised after ingestion and reduces the oxidation of other substrates used for ATP synthesis. The energy conversion factor for alcohol (ethanol) is 29 kJ/g (7 kcal/g).

3.2. Dietary intake data

Estimated energy intakes for children and adolescents in 21 countries and for adults in 24 countries in the European Union are presented in Appendix 2 and Appendix 3, respectively. The data refer to food

[8] Council Directive 90/496/EEC of 24 September 1990 on nutrition labelling for foodstuffs. OJ L 276, 6.10.1990, p. 40–44. Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers, amending Regulations (EC) No 1924/2006 and (EC) No 1925/2006 of the European Parliament and of the Council, and repealing Commission Directive 87/250/EEC, Council Directive 90/496/EEC, Commission Directive 1999/10/EC, Directive 2000/13/EC of the European Parliament and of the Council, Commission Directives 2002/67/EC and 2008/5/EC and Commission Regulation (EC) No 608/200. OJ L 304, 22.11.2011, p. 18–63.

consumption surveys conducted from 1989 onwards. Most studies comprise national representative population samples.

As shown in Appendices 2A and 3A, there is a large diversity in the methodology applied to assess the individual energy intakes of children, adolescents and adults. These differences in dietary assessment methods make direct comparisons difficult. Age classifications may not be uniform and comparability is also hindered by differences in food composition tables used for the conversion of food consumption data to nutrient intake data (Deharveng et al., 1999). Dietary intake data are prone to reporting errors and there may be a varying degree of underreporting in different surveys (Merten et al., 2011).

Although the differences in methodology have an impact on the accuracy of between-country comparisons, the presented data give a rough overview of the energy intake in a number of European countries. Most studies reported mean intakes and standard deviations (SD) or mean intakes and intake distributions.

Available data show that average energy intakes in children aged 2 to 6 years vary between 4.5 (1,076) and 7.9 MJ/d (1,912 kcal/d). Boys usually have somewhat higher energy intakes than girls. In older children, average daily energy intakes vary between 6.8 MJ/d (1,625 kcal/d) in boys aged 5-8 years and 13.2 MJ/d (3,155 kcal/d) in boys aged 13-15 years, and between 6.1 MJ/d (1,458 kcal/d) in girls aged 10-14 years and 10.0 MJ/d (2,390 kcal/d) in girls aged 13-15 years. In adolescents, observed average energy intakes are between 9.9 MJ/d (2,366 kcal/d) in boys aged 15-17 years and 14.7 MJ/d (3,513 kcal/d) in boys aged 16-18 years and between 6.8 MJ/d (1,625 kcal/d) in girls aged 15-18 years and 9.9 MJ/d (2,366 kcal/d) in girls aged 15-17 years.

In adults, average energy intakes vary between 7.1 (1,697 kcal/d) and 15.3 MJ/d (3,657 kcal/d) in men and between 5.7 (1,362 kcal/d) and 11.4 MJ/d (2,725 kcal/d) in women. Ranges vary from 3.1-8.1 MJ/d (741-1,936 kcal/d) at the lower (2.5-10th percentile) end to 8.9-21.0 MJ/d (2,127-5,019 kcal/d) at the upper (90-97.5th percentile) end of the intake distributions. The lowest energy intakes are usually observed in older age groups.

4. Overview of dietary reference values and recommendations

A number of national and international organisations have estimated energy requirements for all age groups and for pregnant and lactating women. They have generally been estimated as TEE, and TEE has been calculated as the product of REE x PAL or from regression equations in which age, sex, body mass and, as the case may be, height are considered. REE (or BEE or BMR, according to the terminology used in the reports) is estimated from different equations and PAL values used vary between countries.

4.1. Adults

Most authorities (AFSSA, 2001; D-A-CH, 2012; FAO/WHO/UNU, 2004; Health Council of the Netherlands, 2001; NNR, 2004; SACN, 2011; SCF, 1993) determined average energy requirements using the factorial approach (Appendix 4). Usually REE was estimated using Schofield’s predictive equations based on body mass (FAO/WHO/UNU, 1985). However, AFSSA (2001) used the predictive equations by Black (1996), whereas SACN estimated REE with the equations by Henry (2005), because they predict slightly lower values compared to Schofield’s equations and estimate REE with a higher accuracy (as determined by Weijs et al. (2008) in overweight/obese subjects). The body masses entered into these equations were either derived from observed heights in the respective country and calculated for a desirable BMI within the healthy BMI range, were based on mean population body masses (NNR, 2004), or used incremental body masses within a defined body mass range (FAO/WHO/UNU, 2004). The calculated REE values were then multiplied with PAL values ranging between 1.4 and 2.4. Some authorities assumed lower PAL values for older people (AFSSA, 2001; D-A-CH, 2012; Health Council of the Netherlands, 2001; SACN, 2011; SCF, 1993), used desirable PAL values (D-A-CH, 2012; Health Council of the Netherlands, 2001; SCF, 1993), and/or defined PAL values or ranges of PAL values representing certain lifestyle activity levels. SACN (2011) derived PAL values based on two DLW studies measuring TEE and measuring (Moshfegh et al., 2008) or calculating (Tooze et al., 2007) REE in middle-aged US adults. The resulting distribution of PAL values was assumed to also represent PAL values of the UK population, and the median PAL value was used to derive average energy requirements according to age and sex.

IoM (2005) collected DLW data on adults separately for those with normal body mass and for overweight/obese subjects. The normal body mass database comprised 169 men and 238 women with a BMI between 18.5 to 25 kg/m^2. Based on this database, the IoM derived prediction equations of TEE by nonlinear regression analysis taking into account age, sex, height, body mass, and a physical activity constant. Four physical activity constants were defined as equivalents to a range of PAL values appropriate for sedentary, low active, active, and very active lifestyles. Individual PAL values were determined by dividing the measured individual TEE values by the measured or predicted individual REE values, and PAL values less than 1.0 or greater than 2.5 were omitted.

4.2. Infants and children

For the determination of energy requirements for infants, it was generally considered that TEE is different for breast-fed and formula-fed infants. Some authorities derived values for formula-fed infants only (AFSSA, 2001; D-A-CH, 2012; SCF, 1993), whereas others estimated energy requirements according to feeding mode (FAO/WHO/UNU, 2004; SACN, 2011) (Appendices 5, 6).

Older estimates of energy requirements of infants were based on measurements of energy intake (FAO/WHO/UNU, 1985; SCF, 1993). More recent estimated energy requirements have been based on measurements of energy expenditure using DLW data from healthy, well-nourished, term infants available from 1987 onwards. The DLW database has subsequently been extended to comprise also older infants and young children up to 24 months of age. The energy expended for growth was estimated from changes in body mass and body composition, i.e. gains in protein and fat mass during growth, and added to the estimated TEE.

The DLW database used by FAO/WHO/UNU (2004) comprised 13 studies with DLW measurements performed on a total of 417 healthy, well-nourished, non-stunted infants from 0 to 12 months of age and growing along the trajectory of the WHO reference standard (1983). Most (11/13) studies were done in the UK, the US, and the Netherlands. Linear regression analysis using body mass as the predictor for TEE was applied. An allowance for energy deposition in tissues during growth was added, which was calculated by gains in protein and fat, and corresponding energy deposition, assuming that the energy equivalents of protein and fat deposition are 23.6 and 38.7 kJ/g (5.64 and 9.25 kcal/g), respectively (Butte et al., 2000b). Since formula-fed infants had higher TEE during the first year of life, separate predictive equations for breast-fed and formula-fed infants were also proposed.

For infants and children up to 2 years of age, the DLW database of IoM (2005) comprised children within the 3^{rd} and 97^{th} percentile for US body mass-for-length values. A single equation involving only body mass was found suitable to predict TEE in all individuals irrespective of sex. Because of the small sample size of the data used and the limited range of estimated physical activity, PAL was not included in the TEE equation. The IoM calculated the estimated energy requirements (EERs) for infants and very young children as TEE plus energy deposition for growth. The energy requirement for deposition was computed from rates of protein and fat deposition in a longitudinal study of infants (0.5-24 months of age) (Butte et al., 2000b), and applied to the 50^{th} percentile of gain in body mass for boys and girls of similar ages (Guo et al., 1991). In children aged 0 to 36 months, a single equation involving only body mass was found suitable to predict TEE in all individuals irrespective of sex (IoM, 2005). EERs were provided for each sex, for each month between one and 35, taking into account reference body masses for the United States (Kuczmarski et al., 2000) and calculated energy deposition allowance (Butte et al., 2000b; Guo et al., 1991).

For older children and adolescents (Appendix 6), FAO/WHO/UNU (2004) derived quadratic predictive equations with body mass as the single predictor from studies of TEE with a total of 801 boys and 808 girls using either the DLW method or HR monitoring (Torun, 2001). Using these predictive equations, TEE was calculated based on the WHO reference values of body mass-for-age (Torun, 2001; WHO, 1983). Predicted values were about 7 % higher than the actual measurements of TEE for infants and young children between one and two years of age, therefore TEE estimates were reduced by that percentage.

Energy deposited in growing tissues was estimated by multiplying the mean daily gain in body mass at each year of age by the average energy deposited in growing tissues (8.6 kJ or 2 kcal per gram of gain in body mass) using the WHO reference values of body mass-for-age (WHO, 1983). A set of values for mean daily energy requirement (MJ or kcal/d) was calculated for each sex, requirements being the sum of energy deposition and TEE. This was then divided by the median body mass at each year to express requirements as energy units per kilogram of body mass.

To account for less or more physically active lifestyles in children aged 6 years and older, it was recommended to subtract or add 15 % of energy requirements as estimated with the use of the predictive equations valid for children and adolescents with “average” physical activity. Examples of activities performed with less active than average physical lifestyles as well as for those performed with vigorous lifestyles were given.

For US children aged 3 to 18 years, EERs were set for boys and girls separately, because of variations in growth rate and physical activity (IoM, 2005) (Appendix 6). DLW data from the normative database with US children within the 5^{th} and 85^{th} percentile of BMI were used to develop equations to predict TEE based on a child’s sex, age, height, body mass and PAL category. The estimated energy deposition was computed based on published rates of gain in body mass (Baumgartner et al., 1986) and estimated rates of protein and fat deposition of children (Fomon et al., 1982) and adolescents (Haschke, 1989). An average of 84 kJ/d (20 kcal/d) for estimated energy deposition for children aged 3 to 8 years, and of 105 kJ/d (25 kcal/d) for children and adolescents aged 9 to 18 years (IoM, 2005) was therefore added to the calculated TEE. Considering American reference body masses and heights (Kuczmarski et al., 2000), a set of EER values was proposed for each sex, each age and the four PAL categories.

For children aged up to 9 years, other authorities used the factorial approach to derive estimated energy requirements, except for the SCF (1993) who based them on measurements of energy intake following the approach of FAO/WHO/UNU (1985) but without adding an allowance of 5 % to allow for a desirable level of physical activity (Appendix 7). Energy expenditure for growth was either accounted for by adding a fixed percentage to the amount of REE x PAL (NNR, 2004) by slightly increasing the PAL value to be multiplied with the REE (SACN, 2011), or by adding average amounts considering deposited protein and fat as well as gain in body mass for the various age groups and considering expenditure for synthesis (AFSSA, 2001; Health Council of the Netherlands, 2001; SCF, 1993).

For older children and adolescents aged 10-17 years, other authorities mostly used the factorial approach to derive energy requirements. REE was usually predicted with the equations developed by Schofield (FAO/WHO/UNU, 1985; Schofield et al., 1985), except for SACN (2011) who used the predictive equations of Henry (2005). PAL values to be multiplied with estimated REE were either based on data from Torun et al. (1996) using the DLW technique (D-A-CH, 2012; Health Council of the Netherlands, 2001; NNR, 2004), were based on calculated average energy expenditure with various daily activities (AFSSA, 2001; SCF, 1993), or were derived from a data set of all published DLW studies of children aged over one year published until 2006 (SACN, 2011).

4.3. Pregnancy

Table 2 lists DRVs for pregnant women set by various authorities (referring to energy intakes above the values for non-pregnant women).

Table 2: Overview of Dietary Reference Values (DRVs) for energy during pregnancy in addition to those for non-pregnant, non-lactating women

	SCF (1993)	Health Council of the Netherlands (2001)	NNR (2004)	FAO/ WHO/UNU (2004)	IoM (2005)	SACN (2011)	D-A-CH (2012)
1st trimester	+ 0.75 MJ/d (+ 180 kcal/d) from the 10th week of pregnancy for women of normal body mass	+ 1.2 MJ/d (+ 290 kcal/d) (whole pregnancy)	negligible	+ 0.35 MJ/d (+ 85 kcal/d)	0	/	+ 1.1 MJ/d (+ 255 kcal/d) (whole pregnancy). To be corrected in case of a change in PAL during pregnancy compared to the non-pregnant state
2nd trimester			+ 1.56 MJ/d (+ 350 kcal/d)	+ 1.2 MJ/d (+ 285 kcal/d)	+ 1.4 MJ/d (+ 340 kcal/d)	/	
3rd trimester			+ 2.1 MJ/d (+ 500 kcal/d)	+ 2.0 MJ/d (+ 475 kcal/d)	+ 1.9 MJ/d (+ 452 kcal/d)	+ 0.8 MJ/d (+ 191 kcal/d)	

In the FAO/WHO/UNU report (2004) the extra amount of energy required during pregnancy was calculated, assuming a mean gestational gain in body mass of 12 kg (WHO, 1995a), by two factorial methods, using either the cumulative increment in REE during pregnancy or the cumulative increment in TEE, plus the energy deposited as protein and fat. In the calculation using the increment in REE, it was assumed that the efficiency in energy utilisation to synthesize protein and fat was 90 %. Adjustments for efficiency of energy utilisation were not necessary in the calculations that used the increment in TEE, as TEE measured with DLW includes the energy expenditure of synthesis. The estimates of the additional energy required during pregnancy were very similar using either REE or TEE for the calculation: 323 MJ (77,100 kcal) and 320 MJ (76,500 kcal), respectively. These values, which were based on experimental data, differ by only 4 % from the theoretical estimate of 335 MJ (80,000 kcal) made by the 1981 FAO/WHO/UNU expert consultation (FAO/WHO/UNU, 1985). Averaging the two factorial calculations, the extra energy expenditure of pregnancy is 321 MJ (77,000 kcal) divided into approximately 0.35 MJ/d, 1.2 MJ/d and 2.0 MJ/d (85 kcal/d, 285 kcal/d and 475 kcal/d) during the first, second and third trimesters, respectively.

IoM (2005) determined the EERs during pregnancy from the sum of the TEE of non-pregnant women plus a median change in TEE of 33.5 kJ/week (8 kcal/week) plus the energy deposition during pregnancy of 753 kJ/d (180 kcal/d) (factorial method). The median TEE change per gestational week was calculated based on a dataset of pregnant women with normal pre-pregnancy BMIs (18.5-25 kg/m^2) and longitudinal DLW measurements of TEE throughout pregnancy. The average TEE per gestational week was computed for each woman and the median values of these data were assumed to represent the general trend. TEE was considered to change little and gain in body mass was considered to be minor during the first trimester, so no increase in energy intake during the first trimester was recommended. It was found that the energy expenditure of pregnancy was not equally distributed over pregnancy. For pregnant women aged 19 to 50 years the EERs were calculated as follows:

$EER_{pregnant}$=$EER_{nonpregnant}$ + additional energy expenditure during pregnancy + energy deposition

1st trimester: $EER_{pregnant} = EER_{nonpregnant} + 0 + 0$

2nd trimester: $EER_{pregnant} = EER_{nonpregnant}$ + 0.7 MJ + 0.7 MJ ($EER_{pregnant} = EER_{nonpregnant}$ + 160 kcal (=8 kcal/wk x 20 wk) + 180 kcal)

3rd trimester: $EER_{pregnant} = EER_{nonpregnant} + 1.2$ MJ + 0.7 MJ ($EER_{pregnant} = EER_{nonpregnant} + 272$ kcal (=8 kcal/wk x 34 wk) + 180 kcal)

For pregnant women aged 14 to 18 years the same equations were applied, taking into account the adolescent $EER_{nonpregnant}$ instead of the adult $EER_{nonpregnant}$.

In the SACN report (2011) it was considered that the energy reference values for pregnancy estimated by the factorial method (as in the reports of FAO/WHO/UNU (2004) and IoM (2005)) exceed energy intakes observed in populations of well-nourished pregnant women giving birth to infants with an average body mass in the healthy range. Consequently, it was considered that there was no reason to amend the increment of 0.8 MJ/d in the last trimester previously recommended (DoH, 1991). It was also indicated that women entering pregnancy as overweight may not require the increment but data were insufficient to derive a recommendation for this subgroup.

The Nordic Nutrition Recommendations (2004) indicated that energy requirement during pregnancy based on total energy expenditure and total energy deposition had been estimated for women of normal body mass. They considered that the increase in EER was negligible in the first trimester and increased by 1.56 MJ/d (350 kcal/d) and 2.1 MJ/d (500 kcal/d) in the second and third trimesters, respectively (NNR, 2004).

The German-Swiss-Austrian reference values (D-A-CH, 2012) stated that for the whole duration of pregnancy additional 300 MJ (71,100 kcal) were needed, and recommended to distribute this amount evenly throughout pregnancy. This corresponds to an additional energy intake of 1.1 MJ/d (255 kcal/d). In case of a change in physical activity levels during pregnancy compared to the non-pregnant state, the additional energy intakes had to be corrected accordingly.

AFSSA (2001) did not set any reference values for energy during pregnancy and commented on the spontaneous adaptation of the energy intakes of women during pregnancy and the importance of a weight gain in the recommended range.

The Health Council of the Netherlands (2001) concluded that the average extra energy expenditure of pregnancy was 1.5 MJ/d (based on the factorial method and assuming an unchanged pattern of activity). However, as women generally tend to be less physically active during pregnancy, the extra energy requirement during pregnancy was estimated to be 1.2 MJ/d, derived from data based on the DLW technique applied in small sets of Swedish, British and US pregnant women.

SCF (1993) provided estimates of the additional daily energy requirements (from 10th week of pregnancy) according to pre-pregnancy BMI (18.5-19.9, 20.0-25.9, >25.9 kg/m^2), considering the corresponding gain in body mass (12.5-18 kg, 11.4-16 kg, 7-11.5 kg), and assuming that all women were 1.65 m in height and moderately active (average PAL of 1.64 before pregnancy). Because of possible adjustment in either physical activity or metabolism by the second trimester of pregnancy, the SCF considered it reasonable to halve the supposed extra energy demand, which therefore would be 0.75 MJ/d (179 kcal/d) from the 10th week of pregnancy for women with a normal body mass.

4.4. Lactation

Table 3 lists DRVs for energy for lactating women set by various organisations (referring to energy intakes above the values for non-pregnant women).

Table 3: Overview of Dietary Reference Values for energy during lactation in addition to those for non-pregnant women

	0-6 months *post partum*	**From 6 months *post partum* onwards**
SCF (1993)	0-1 months: + 1.5 MJ/d (+ 359 kcal/d) 1-2 months: + 1.8 MJ/d (+ 430 kcal/d) 2-3 months: + 1.92 MJ/d (+ 459 kcal/d) 3-6 months: + 1.71 MJ/d (+ 409 kcal/d)	Minor weaning practice from 6 months: + 1.92 MJ/d (+ 459 kcal/d) Substantial weaning practice from 6 months: + 0.88 MJ/d (+ 210 kcal/d)
Health Council of the Netherlands (2001)	+ 2.1 MJ/d (+ 502 kcal/d)	
NNR (2004)	+ 2.0 MJ/d (+ 478 kcal/d)	
FAO/ WHO/UNU (2004)	First 6 months: In well-nourished women with adequate gain in body mass: + 2.1 MJ/d (+ 505 kcal/d).	Second 6 months: variable.
IoM (2005)	First 6 months: + 1.4 MJ/d (+ 330 kcal/d)	Second 6 months: + 1.7 MJ/d (+ 400 kcal/d)
SACN (2011)	First 6 months: + 1.4 MJ/d (+ 330 kcal/d)	Second 6 months: depends on breast milk intake of infant and maternal body composition
D-A-CH (2012)	First four months: + 2.7 MJ/d (+ 635 kcal/d). After four months: + 2.2 MJ/d (+ 525 kcal/d) in women exclusively breastfeeding); + 1.2 MJ/d (+ 285 kcal/d) in women gradually introducing complementary feeding). To be corrected in case of change in PAL compared to the non-pregnant state.	

According to FAO/WHO/UNU (2004), total energy requirements during lactation are equal to those of the pre-pregnancy period, plus the additional demands imposed by the need for adequate milk production and secretion. For women who feed their infants exclusively with human milk during the first six months of life, the mean energy expenditure over the six-month period is 2.8 MJ/day (675 kcal/d; 807 g milk/d x 2.8 kJ/g / 80 % efficiency). From the age of six months onwards, when infants are partially breastfed and milk production is on average 550 g/d, the energy expenditure imposed by lactation is 1.9 MJ/d (460 kcal/d). Fat stores accumulated during pregnancy may cover part of the additional energy needs in the first months of lactation. Assuming an energy factor of 27.2 MJ/kg body mass (Butte and Hopkinson, 1998; Butte and King, 2002), the rate of loss in body mass in well-nourished women would correspond to the mobilisation of 27.2 x 0.8 kg/month = 21.8 MJ/month, or 0.72 MJ/d (170 kcal/d) from body energy stores. This amount of energy can be subtracted from the 2.8 MJ/d (675 kcal/d) required during the first six months of lactation for milk production in well-nourished (but not in undernourished) women. The result, 2.1 MJ/d (505 kcal/d), is similar to the additional energy required when infants are partially breast-fed after six months of lactation. Undernourished women and those with insufficient gestational gain in body mass should increase their energy intake by 2.8 MJ/d (675 kcal/d) during the first six months of lactation. Energy requirements for milk production in the second six months are dependent on rates of milk production, which are highly variable among women and populations.

In the report of IoM (2005), TEE values were derived from DLW data on lactating women with normal pre-pregnancy BMIs (18.5-25 kg/m^2) and fully breast-feeding their infants at one, two, three, four and six months *post partum*. These TEE values include the energy needed for milk synthesis. A comparison of the measured TEE of lactating women and the TEE calculated from age, height, body mass and PAL (using the IoM prediction equation for adult women) showed that the differences were minimal.

Therefore, using a factorial approach, the IoM estimated the EERs during lactation from the EER for adult women with a normal body mass, taking into account milk energy outputs, and energy mobilisation from tissue stores (loss of body mass). In the first six months *post partum* it was considered that well-nourished lactating women experienced an average loss of body mass of 0.8 kg/month equivalent to 0.7 MJ/d (170 kcal/d). Stability of body mass was assumed after six months *post partum*. The milk energy output was considered to be around 2.1 MJ/d (500 kcal/d) in the first six months and 1.7 MJ/d (400 kcal/d) in the second six months (calculated from the milk production rate and its energy content). For lactating women (19 years or older), the EERs were set as follows:

$EER_{lactation}$=$EER_{pre\text{-}pregnancy}$ + milk energy output – energy from body mass loss

0-6 months: $EER_{lactation}$ = adult $EER_{pre\text{-}pregnancy}$ + 2.1 MJ – 0.7 MJ ($EER_{lactation}$ = adult $EER_{pre\text{-}pregnancy}$ + 500 kcal – 170 kcal)

7-12 months: $EER_{lactation}$ = adult $EER_{pre\text{-}pregnancy}$ + 1.7 MJ – 0 ($EER_{lactation}$ = adult $EER_{pre\text{-}pregnancy}$ + 400 kcal – 0)

For lactating women aged 14 to 18 years the same equations apply, taking into account the adolescent $EER_{pre\text{-}pregnancy}$ instead of the adult $EER_{pre\text{-}pregnancy}$.

SACN (2011) followed the same factorial method as IoM (2005) for the first six months of lactation.

The Nordic Nutrition Recommendations (2004) estimated the extra need for energy during lactation based on the energy content of breast milk per gram, which was considered as approximately 2.8 kJ/g (0.67 kcal/g), multiplied by the production of breast milk during the whole weaning period. The average mobilisation of fat from stores to satisfy energy needs was taken into account. A reference value of 2.0 MJ/d (478 kcal/d) for an extra energy intake during lactation was suggested.

The German-Swiss-Austrian reference values (D-A-CH, 2012) calculated an additional energy requirement for lactating women of 2.7 MJ/d (635 kcal/d) for the first four months *post partum*. After four months, a distinction was made between women exclusively breastfeeding and women partially breastfeeding. For the first group, an additional energy requirement of 2.2 MJ/d (525 kcal/d) was estimated, and for the latter 1.2 MJ/d (285 kcal/d). In case PAL was changed during lactation compared to the pre-pregnant state, the additional energy intake was to be corrected accordingly.

AFSSA (2001) did not set any reference values for energy during lactation and commented on the adaptation of the energy expenditure during lactation and the use of body stores.

The Health Council of the Netherlands (2001) calculated the average extra energy requirement during lactation based on the energy value of human milk plus the energy required to produce it. Considering the total energy content of human milk to be approximately 2.7 kJ/mL (0.65 kcal/mL) and the average amount of milk secreted to be 800 mL/d, the amount of energy secreted via human milk was calculated to be approximately 2.2 MJ/d (525 kcal/d). Assuming an efficiency of conversion of energy from food to human milk of 80 %, the energy expenditure of lactation was considered to be 2.7 MJ/d (635 kcal/d). Taking into account the average decrease in body fat of 0.5 kg per month of lactation, the Health Council of the Netherlands estimated the average extra energy requirement during lactation to be 2.1 MJ/d (502 kcal/d).

The Scientific Committee on Food (1993) proposed values for additional energy requirements for lactation derived from the UK COMA Committee (DoH, 1991), but applied an efficiency value of 95 % for milk production. In case of full breast-feeding, total extra requirements were set for zero to one, one to two, two to three and three to six months, taking into account milk volume, energy expenditure and an average allowance for loss of body mass (0.5 kg/month following delivery). From 6 months onwards, minor or substantial complementary feeding practices were considered separately, taking into account the same previous three parameters (milk volume, energy expenditure and an average allowance for loss of body mass).

5. Criteria and approaches for the derivation of the Average Requirement (AR) for energy

5.1. Criteria

5.1.1. Energy balance

Energy balance is achieved when metabolisable energy intake is equal to TEE, which includes the energy deposited in new tissue in growth and in pregnancy and the energy secreted in milk in lactation. A positive energy balance occurs when energy intake is in excess of these requirements, whereas a negative energy balance occurs when energy needs are not met by intake. When energy balance is maintained over a prolonged period, an individual is considered to be in a steady state. This can include short periods during which the day-to-day balance between intake and expenditure is not obtained. Short-term, day-to-day energy imbalances are associated with the deposition and mobilisation of glycogen and fat. In terms of regulation of body mass it is important to consider the overall energy balance over a prolonged period of time.

Within certain limits humans can adapt to transient or long-term changes in energy intake through various physiological and behavioural responses related to energy expenditure and/or changes in growth. Energy balance is then achieved at a new steady state. However, adjustments to low or high energy intakes entail biological and behavioural penalties, such as reduced growth velocity, loss of lean body mass, excessive accumulation of body fat, increased risk of disease, forced rest periods, and physical or social limitations in performing certain activities and tasks. Therefore, estimated energy requirements should be based on the amounts of energy necessary and sufficient to maintain energy balance in healthy adult men and women who are maintaining a desirable body mass and level of activity (FAO/WHO/UNU, 2004). Correspondingly, the increments in energy requirements for growth, pregnancy and lactation should be ascertained in healthy children and women with desirable growth rates and development or desirable courses of pregnancy and lactation, respectively. Ageing is accompanied by changes in energy balance. The heterogeneity in the alteration of body mass, body composition, and physical activity during the course of biological ageing should be taken into account in the derivation of the AR for older adults.

5.1.2. Body mass, body mass index (BMI) and body composition

Because mortality and risk of diseases increases with both high and low BMI values, a stable body mass within target BMI values is desirable. An obesity task force has defined the healthy BMI of adults to be between 18.5 and 24.9 kg/m² (WHO, 2000). BMI values outside this target range have been found to be associated with increased morbidity and mortality. In this Opinion, a BMI of 22 kg/m², as the midpoint of this range of healthy BMI, will be used for the calculation of average energy requirements of adults.

Stable body mass is a simple indicator of the adequacy of energy intake that matches energy expenditure in the long term. The main disadvantages of relying on body mass and BMI are that they do not reliably reflect body fat, which is an independent predictor of disease risk (IoM, 2005; Willett et al., 1999). Although sophisticated techniques are available to precisely measure FFM and FM of individuals, these techniques have not generally been applied in clinical and epidemiological studies investigating the associations with morbidity and mortality. Therefore, BMI, although only an indirect indicator of body composition, is used to classify underweight and overweight individuals, and as the target parameter for AR for energy.

BMI has a different relation to fat and muscle mass among the elderly than among younger individuals due to age-related changes in body mass and its composition. There is also a reduction in stature with age of 1-2 cm/decade, which has been reported to begin at about 30 years of age and to become more rapid at older ages (Sorkin et al., 1999). Because of these age-related changes in elderly populations, the BMI may not have the same associations with morbidity and mortality as in younger to middle aged adults. As BMI by itself seems to have only limited explanatory power with regard to morbidity and mortality in older persons, the Panel concludes that additional indices such as body composition (i.e. FM, FFM, muscle mass, fat distribution, age-related changes in body height) should also be considered.

There are specific target BMI values for children because desirable BMI changes with age. On average, a rapid increase of the BMI occurs during the first year of life. The BMI subsequently declines, reaches a minimum around four to six years, and then gradually increases up to the end of growth (“adiposity rebound”) (IoM, 2005; Kuczmarski et al., 2000; Rolland-Cachera et al., 2006). Cut-off points to define underweight and overweight can be established by using growth charts of healthy children living in an environment that supports optimal growth and development such as the most recent WHO Child Growth Standards (Butte et al., 2007; WHO, 2007; WHO Multicentre Growth Reference Study Group, 2006). According to the WHO classifications for overweight and obesity in younger children (0-5 years), children above +1 SD of the age-specific mean BMI are described as being “at risk of overweight”, above +2 SD as overweight, and above +3 SD as obese. For school-aged children and adolescents, growth curves that accord with the WHO Child Growth Standards for preschool children and the BMI cut-offs for adults were constructed with merged data from the 1977 National Center for Health Statistics (NCHS/WHO) growth reference (1-24 years) and data from the under-fives growth standards’ cross-sectional sample (18-71 months). Overlapping of the age ranges allowed to smooth the transition between the two samples (de Onis et al., 2007). For older children, the WHO adolescence BMI-for-age curves at 19 years closely coincide with adult overweight (BMI 25) at +1 SD and with adult obesity (BMI 30) at +2 SD. As a result, these SD classifications to define overweight and obesity were applied to children aged 5-19 years (de Onis and Lobstein, 2010).

5.1.3. Body mass gain in pregnancy

There is substantial variance in reported gestational increases in body mass (Fraser et al., 2011; Herring et al., 2008) that is the major determinant of the incremental energy needs during pregnancy. The WHO Collaborative Study on Maternal Anthropometry and Pregnancy Outcomes identified gestational increase in body mass associated with an optimal ratio of maternal and foetal health outcomes[9] to be between 10–14 kg (mean, 12 kg) (WHO, 1995a).

Both low and excessive gestational increases in body mass are related to adverse outcomes of pregnancy (IOM/NRC, 2009). Higher maternal gestational increases in body mass are associated with a decreased risk for small-for-gestational-age (SGA) infants (especially among underweight women) but are associated with increased risk for large-for-gestational-age (LGA) infants, low 5-minutes Apgar scores, gestational diabetes, preeclampsia, failed labour induction, ceasarean delivery, *post partum* infection and *post partum* body mass retention; on the other hand, an inadequate gestational increase in body mass increases the risk of foetal death, preterm labour and delivery, and infants with low body mass at birth (DeVader et al., 2007).

Evidence from the scientific literature is consistent in showing that pre-pregnancy BMI is an independent predictor of many adverse outcomes of pregnancy (IOM/NRC, 2009; Kiel et al., 2007; Stotland et al., 2006). Thus, in the most recent IOM report (IOM/NRC, 2009), ranges for the increase in body mass have been recommended by pre-pregnancy BMI (<18.5 kg/m^2: 12.5-18 kg, 18.5-24.9 kg/m^2: 11.5-16 kg, 25.0-29.9 kg/m^2: 7-11.5 kg, $\geq$ 30.0 kg/m^2: 5-9 kg). However, lower gestational increases in body mass of 2-10 kg in women with a pre-pregnancy BMI between 20-24.9 kg/m^2 (Cedergren, 2007) and even moderate losses of body mass in overweight (0.03 kg/week) and obese (0.019 kg/week) women (Oken et al., 2009) have also been associated with optimal maternal and foetal outcomes.

[9] For the mother in terms of maternal mortality, complications of pregnancy, labour and delivery, *post partum* weight retention and lactational performance, and for the infant in terms of foetal growth, gestational duration, mortality and morbidity.

The Panel concludes that an intake corresponding to ARs for energy for pregnancy based on a target gestational increase in body mass of around 12 kg is most likely to be associated with optimal maternal and foetal health outcomes in women with pre-pregnant BMIs in the range between 18.5 and 24.9 kg/m² (WHO, 1995a).

5.1.4. Physical activity

A certain amount of habitual physical activity is desirable for biological and social well-being. The health benefits of regular physical activity and improved physical fitness are well documented (Blair et al., 2001) and many of the known health benefits of physical exercise result, either directly or indirectly, from the beneficial effects on the maintenance of a healthy body mass and body composition. Regular exercise may help to preserve (Forbes, 2000) or to increase (Teixeira et al., 2003) FFM. Because FFM has a relatively high metabolic activity, it is an important determinant of energy expenditure at rest (Halliday et al., 1979).

There is consensus among experts that a habitual PAL of 1.70 or higher is associated with a lower risk of overweight and obesity, cardiovascular disease, diabetes and several types of cancer, osteoporosis, and sarcopenia (FAO/WHO/UNU, 2004).

Habitual physical activity, and hence TEE, decreases after a given age (Black et al., 1996; Roberts, 1996), and in advanced age PAL values can be very low. In free- and independently living healthy Swedish men and women aged 91-96 years PAL values were on average only 1.38 (Rothenberg et al., 2000). In a cohort of community-dwelling US older adults (aged 70-82 years) who are described as high-functioning, able to independently perform activities of daily living, and with no evidence of life-threatening illnesses, a wide variation of PAL values was observed, with an overall mean PAL value of 1.70 (Moshfegh et al., 2008; Tooze et al., 2007). Some elderly individuals who have remained physically active are even able to maintain high levels of energy expenditure, with PAL values as high as 2.48 (Reilly et al., 1993; Withers et al., 1998). This indicates that the age at which TEE and energy requirements start decreasing depends on individual, social and cultural factors that promote or limit habitual physical activity among older adults. Information on the relationship between PAL and mortality has been published in a prospective study of healthy older adults (aged 70-82 years) (Manini et al., 2006). Over an average of 6.15 years of follow-up, participants in the upper tertile of EEPA (PAL greater than 1.78) had a significantly reduced risk of all-cause mortality than those in the lowest tertile (PAL less than 1.57).

In children, the regular performance of physical activity in conjunction with good nutrition is associated with health, adequate growth and well-being, improved academic performances, and probably with lower risk of disease in adult life (Boreham and Riddoch, 2001; Torun and Viteri, 1994; Viteri and Torun, 1981). Children who are physically active explore their environment and interact socially more than their less active counterparts. There may also be a behavioural carry-over into adulthood, whereby active children are more likely to be active adults, with the ensuing health benefits of exercise (Boreham and Riddoch, 2001).

The level of physical activity within a population is very variable and may deviate from what is desirable. Thus, ARs for energy based on desirable PALs may promote an energy intake exceeding the actual energy expenditure, and thereby favour an undesirable increase in body mass. The Panel concludes that AR for energy should be given for specified activity levels in consideration of the actual rather than desirable PALs of population groups.

5.2. Approaches

In principle there are two approaches for determining the AR for energy:

The **first** one is the factorial method to estimate TEE. It was originally proposed by FAO/WHO/UNU (1985) and adopted by the most recent FAO/WHO/UNU report for calculating energy requirements of adults (FAO/WHO/UNU, 2004). This approach involves the calculation of TEE as PAL x REE, where

REE is predicted from anthropometric measures, and PAL can be estimated either from time-allocated lists of daily activities expressed as PAR values or, alternatively, by dividing TEE (measured by the DLW method) by REE which was measured by indirect calorimetry or calculated with predictive equations. Advantages of this approach are that it accounts for the diversity in body size, body composition and habitual physical activity among adult populations with different geographic, cultural and economic backgrounds, and therefore can be universally applied (FAO/WHO/UNU, 2004).

The **second** approach is to use TEE, as measured by the DLW method, directly to derive regression equations which describe how TEE varies as a function of anthropometric variables (such as body mass and height) for defined population groups. This approach has been applied by FAO/WHO/UNU (FAO/WHO/UNU, 2004) for children and by IoM (2005) for the US Dietary Reference Intake (DRI) values for energy for all population groups except lactating women. For children and non-pregnant adults (IoM, 2005), the level of physical activity was accommodated within the regression by designating an activity constant for each individual calculated from TEE and REE values in the data sets. One of four physical activity constants representing a predefined PAL range was used (sedentary, low active, active, very active). In this way, sex-specific regression equations for the prediction of TEE were identified based on age, body mass, height and physical activity categories.

Although the DLW data set assembled for the US DRI report (IoM, 2005) includes most of the UK studies published up until the writing of that report, SACN (2011) considered this data set as not being suitable for their approach because study subjects were not recruited explicitly as a representative sample of the UK or any other adult population; furthermore, several of these DLW studies involved investigations of physical activity measurement devices (e.g. accelerometers), and specifically recruited subjects with relatively high activity lifestyles. Instead, for adults, SACN (2011) considered two studies of energy expenditure measured using the DLW method, the OPEN study (n=451, 40-69 years) (Subar et al., 2003; Tooze et al., 2007) and the Beltsville study (n=476; 30-70 years) (Moshfegh et al., 2008). Both studies comprised an urban population with subjects recruited from the Washington DC metropolitan area who were considered as comparable to the current UK population as regards distribution of BMI values and ethnic mixture. However, no objective measures of physical activity were made in either study. Therefore, regression modelling as an approach to derive AR for energy was abandoned by SACN because of the inability of TEE prediction models to account for variation in EEPA.

The Panel notes that in addition to these objections, the normative database from which the regression equations were derived by IoM (2005) includes only a small number of individuals who were not randomly selected (adults aged 19 to 96 years: 238 women, 169 men, children 3 to 18 years: 358 girls, 167 boys). Furthermore, although SACN considered subjects of the OPEN study (Subar et al., 2003, Tooze et al., 2007) and the Beltsville study (Moshgfegh et al, 2008) to be comparable to the UK population, in a validation study with DLW measurements in a small adult population in the UK (n=66) PAL values (1.81 and 1.74 for men and women, respectively) were on average higher than those of the OPEN and Beltsville studies (mean PAL value 1.63) (Ruston et al., 2004). This could indicate either recruitment bias or, in fact, differences between the populations. It is also questionable whether this limited number of subjects from an urban population of the Washington DC area is representative of the European population. Moreover, data are lacking for some age groups (18-29 years and >70 years), or these age groups are underrepresented and interpolations would have to be performed.

Therefore, consistent with SACN (2011), the Panel decides not to use regression modelling to determine AR for energy for children and adults and to follow the factorial approach which is supported by larger data sets. For similar reasons related to the available DLW data, the Panel decides not to derive PAL values by dividing TEE (from DLW studies) by REE (measured or estimated).

5.3. Derivation of energy requirements of various population groups

5.3.1. Adults

For adults the application of the factorial method for estimating TEE is considered to be the most suitable as it accounts for the diversity in body size, body composition and habitual physical activity among adult populations with different geographic, cultural and economic backgrounds, and therefore allows a universal application (FAO/WHO/UNU, 2004).

5.3.1.1. Calculation of resting energy expenditure (REE)

The Panel calculated REE for men and women aged between 18 and 79 years based on individual body heights measured in nationally representative surveys in 13 EU countries, and body masses calculated to yield a BMI of 22 kg/m^2 (see Table 4).

Table 4: Median of measured body heights and body masses of 16,500 men and 19,696 women in 13 EU Member States[10] compared to body masses calculated for a BMI of 22 kg/m^2

Age (years)	n	Measured body height (cm) Median	Measured body mass (kg) Median	Body mass (kg) assuming a BMI of 22 kg/m^2 [1] Median
Men				
18 - 29	2,771	178	77.0	69.7
30 - 39	2,971	178	83.0	69.3
40 - 49	3,780	176	84.0	68.1
50 - 59	3,575	175	84.0	67.3
60 - 69	2,611	174	81.0	66.2
70 - 79	792	172	81.0	65.1
Women				
18 - 29	3,589	164	61.4	59.2
30 - 39	3,866	164	64.4	58.8
40 - 49	4,727	163	67.0	58.5
50 - 59	4,066	161	69.4	57.2
60 - 69	2,806	160	68.3	56.3
70 - 79	915	159	70.1	55.6

[1] Body masses calculated for individual measured body heights assuming a BMI of 22 kg/m^2.

For the prediction of REE with the equations of Harris-Benedict (1919), Schofield et al. (1985), Mifflin et al. (1990), Müller et al. (2004) and Henry (2005) (see Section 2.4.1.), individual data from 36,469 subjects were used (for details of the database and calculation see Appendices 8 and 11). Figure 1 illustrates the median REE values according to age group and sex obtained with the respective equations. Predicted REE decreases with age for both sexes. For women, the Mifflin predictive equation predicted lowest in all age groups $\geq$ 30 y. For men, there is no equation always predicting lowest. For both sexes, the Harris-Benedict equation predicted highest for the ages 18-29 and 30-39 years, whereas Schofield predicted highest for the ages 40-49 and 50-59 years.

As is illustrated in Figure 1, the discrepancy in the results for REE calculated with the various prediction equations becomes larger with increasing age (from 5 % at age 18-29 years to 11-13 % at age 70-79 years).

[10] Bulgaria, Czech Republic, Finland, France, Germany, Ireland, Luxembourg, Poland, Portugal, Slovakia, Spain, The Netherlands, United Kingdom

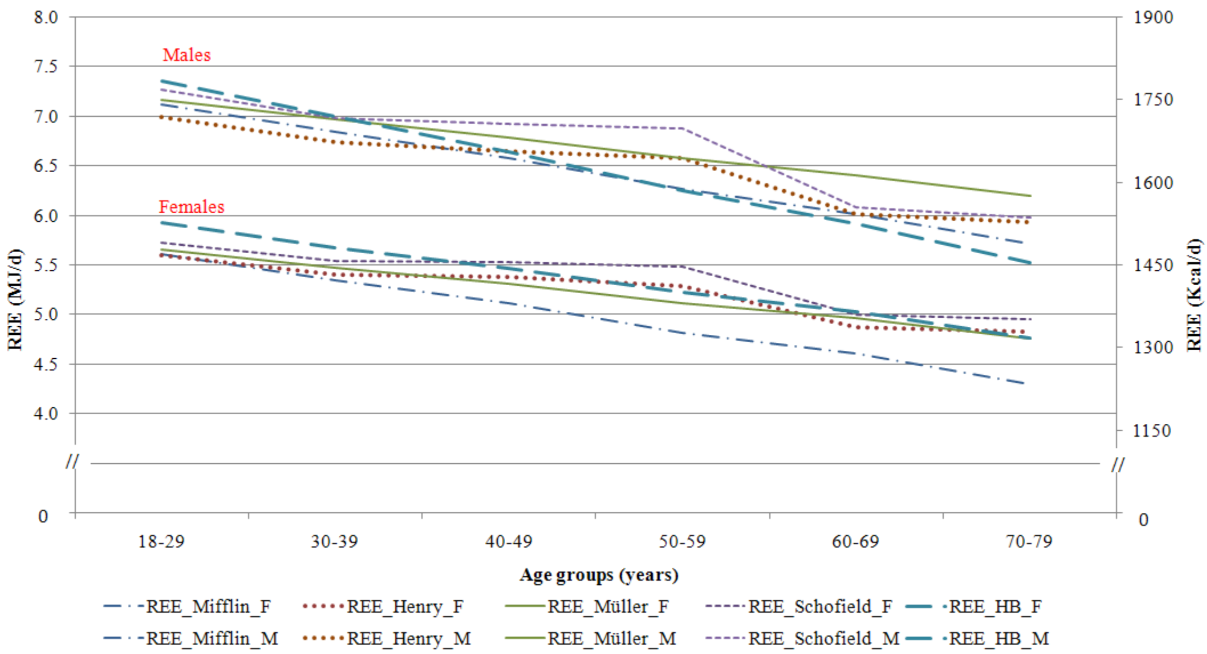

Figure 1: REE (median) for adult men (n=16,500) and adult women (n=19,969) calculated with the equations of Harris-Benedict (1919), Schofield et al. (1985), Mifflin et al. (1990), Müller et al. (2004) and Henry (2005) using body heights measured in nationally representative surveys in 13 EU Member States and corresponding body masses to yield a BMI of 22 kg/m^2

The predictive validity of these equations with regard to older adults has been tested in a sample of free-living older persons. A data set of measurements of REE by indirect calorimetry in 551 elderly subjects (385 women and 165 men, age range 60-96 years) participating in the GISELA study (Lührmann et al., 2010) was used. Agreement between REE predicted with the equations listed above and measured REE was assessed by the method of Bland-Altman (Bland and Altman, 1987). The results confirm the differences in the accuracy of the various equations (Appendix 9). In the female subjects the equation of Schofield et al. (1985) performed best, followed by the equations of Müller et al. (2004), Henry (2005), Harris-Benedict (1919) and Mifflin et al. (1990), while in the male subjects the equation of Müller et al. (2004) performed best, followed by the equations of Henry (2005), Schofield et al. (1985), Harris-Benedict (1919) and Mifflin et al. (1990). With the exceptions of the equation of Schofield et al. (1985) for females and the equation of Müller et al. (2004) for males, all equations underestimated REE as compared to measured values. This evaluation also confirms that the equation of Mifflin et al. (1990) underestimates REE expenditure considerably, at least in GISELA subjects (who, however, are not a representative sample for this age range and can be considered as above average active and health conscious). The accuracy of REE values predicted by these equations with REE measured by indirect calorimetry varied from 74 % (Schofield equation) to 33 % (Mifflin equation) and from 72 % (Müller equation) to 57 % (Mifflin equation) for female and male subjects, respectively.

The Panel considers that there is presently no equation to accurately predict REE, even at a group level, and no prospect that such an equation will be developed in the near future. Differences in average body mass, height and body composition between populations, the influence of sex and ethnicity on body mass and composition, and the decrease in REE that occurs with ageing combine to create a complex figure that cannot be resolved by one single equation.

For this Opinion, the Panel applied all five predictive equations. The range of predicted REE obtained with the equations of Harris and Benedict (1919), Schofield et al. (1985), Mifflin et al. (1990), Müller et al. (2004) and Henry (2005) is obvious from the respective lowest and highest median values calculated with these equations (Table 5) and points to the variability in REE of populations. Depending on the equation used, respective results for lowest and highest median REE differ between 0.3 and 0.7 MJ/d within a sex and age group. Because FFM is the main determinant of REE, at a given BMI equations yielding values for REE at the lower end may be more appropriate for populations with a higher percentage of body fat, compared to those with a higher percentage of FFM.

5.3.1.2. Selection of physical activity level (PAL) values

FAO/WHO/UNU (1985), as well as SACN (2011), identified the lower limit of PAL to be 1.27, which is consistent with studies in non-ambulatory chair-bound and non-exercising subjects performed in a calorimeter (where PAL values of 1.17-1.27 were observed) (Black, 1996). The lower limit of energy expenditure in subjects performing only the minimal activities associated with daily living is between 1.35 and 1.4 (Alfonzo-Gonzalez et al., 2004; Goran et al., 1994a; SACN, 2011; Warwick, 2006). The upper limit to human physical activity is that exhibited for limited periods of time by elite endurance athletes and soldiers on field exercises, for whom PAL values between 3 and 4.7 have been reported (Black, 1996; Hoyt and Friedl, 2006). The maximum PAL value associated with a sustainable lifestyle within the general population appears to be about 2.5 (Black et al., 1996; SACN, 2011; Westerterp and Plasqui, 2004). Low active people can increase their PAL significantly by regular exercise. Examples of the extent of changes in PAL associated with various activities can be extracted from studies that imposed a programme of training on free-living people normally undertaking very little strenuous exercise (Bingham et al., 1989; Blaak et al., 1992; Westerterp et al., 1992). For example, in these studies, 60 minutes of brisk walking at between >6 and <7.5 km/h daily resulted in an increase in PAL of 0.2 while 60 minutes of jogging at 9 km/h daily increased PAL value by 0.4.

SACN derived PAL values from the combined data set of the OPEN (Subar et al., 2003, Tooze et al., 2007) and the Beltsville study (Moshfegh et al., 2008) by dividing TEE by REE measurements (SACN, 2011). There was no evidence of any significant variation of PAL with either body mass or sex. Regression analysis did show that PAL values decrease slightly with age. However, age explained < 1 % of the variance (i.e. PAL = 1.69 at 30 years and 1.63 at 70 years). It was concluded that energy reference values can be defined independently of age at least up to the age of 70 years.

A meta-analysis of studies that involved a total of 319 men and women from 18 to 64 years of age showed a modal value for PAL of 1.60 (range 1.55 to 1.65) for both men and women (Black et al., 1996). For the most part, subjects were from affluent societies in developed countries. Typical sub-populations included students, housewives, white-collar or professional workers, and unemployed or retired individuals; only three persons were specifically identified as manual workers. Hence, the authors of the meta-analysis defined the study participants as people living a "predominantly sedentary Western lifestyle".

SACN (2011) used the distribution of PALs observed in the combined OPEN (Subar et al., 2003; Tooze et al., 2007) and Beltsville (Moshfegh et al., 2008) data sets and defined the median PAL (1.63) as the assumed population activity level (categorized as moderate active) and the 25th (1.49) and 75th percentile (1.78) boundary PAL values as reference values for population groups of men and women thought to be less (low) or more (high) active than average. Although this approach of deriving PAL values took advantage of the measurement of TEE in free living conditions by the DLW method, the Panel decided not to adopt it for defining reference PAL values for the population of the EU because of its limitations outlined under Section 5.2.

Furthermore, within the data set of DLW studies in healthy adults assembled for the SACN report, all of the studies which report PAL values were examined for descriptions of the activities/lifestyles of the subjects. PAL values were assigned to three categories of light, moderate or heavy activity. The values show that the range of PAL values is considerable within subjects classified as exhibiting similar lifestyles, and demonstrate only a weak relationship between lifestyle or self-reported physical activity and PAL.

The Panel therefore decided to apply PAL values of equal steps within the observed range of physical activity levels associated with a sustainable lifestyle for calculating AR for energy. In this way, PAL values can be allocated to lifestyles where values of 1.4, 1.6, 1.8, 2.0 and >2.0 indicate low active, moderately active, active, very active and highly active lifestyles, respectively (Table 5).

5.3.1.3. Ranges of Average Requirement (AR) for energy for adults

Estimated ARs of adults in the EU, based on the factorial method using respective lowest and highest median REE calculated as described above (Section 5.3.1.1. and Appendix 12A) and PAL values of 1.4 through 2.4 in steps of 0.2 increments, are presented in Table 5. The figures illustrate the variability in AR among the population of the EU as a function of REE and PAL. The impact of the variability in REE, resulting from the use of the different predictive equations, on AR requirements at a given BMI and PAL is in the range of 0.4 MJ/d up to 1.7 MJ/d.

Table 5: Ranges of Average Requirement (AR) for energy for adults with six different physical activity levels (PALs)

Age (years)	Lowest median REE (MJ/d)	Highest median REE (MJ/d)	Range of AR at PAL = 1.4 (MJ/d)[1]	Range of AR at PAL = 1.6 (MJ/d)[1]	Range of AR at PAL = 1.8 (MJ/d)[1]	Range of AR at PAL = 2.0 (MJ/d)[1]	Range of AR at PAL = 2.2 (MJ/d)[1]	Range of AR at PAL = 2.4 (MJ/d)[1]
Men								
18-29	7.0	7.4	9.8 - 10.4	11.2 - 11.8	12.6 - 13.3	14.0 - 14.8	15.4 - 16.3	16.8 - 17.8
30-39	6.7	7.0	9.4 - 9.8	10.7 - 11.2	12.1 - 12.6	13.4 - 14.0	14.7 - 15.4	16.1 - 16.8
40-49	6.6	6.9	9.2 - 9.7	10.6 - 11.0	11.9 - 12.4	13.2 - 13.8	14.5 - 15.2	15.8 - 16.6
50-59	6.2	6.9	8.7 - 9.7	9.9 - 11.0	11.2 - 12.4	12.4 - 13.8	13.6 - 15.2	14.9 - 16.6
60-69	5.9	6.4	8.3 - 9.0	9.4 - 10.2	10.6 - 11.5	11.8 - 12.8	13.0 - 14.1	14.2 - 15.4
70-79	5.5	6.2	7.7 - 8.7	8.8 - 9.9	9.9 - 11.2	11.0 - 12.4	12.1 - 13.6	13.2 - 14.9
Women								
18-29	5.6	5.9	7.8 - 8.3	9.0 - 9.4	10.1 - 10.6	11.2 - 11.8	12.3 - 13.0	13.4 - 14.2
30-39	5.3	5.7	7.4 - 8.0	8.5 - 9.1	9.5 - 10.3	10.6 - 11.4	11.7 - 12.5	12.7 - 13.7
40-49	5.1	5.5	7.1 - 7.7	8.2 - 8.8	9.2 - 9.9	10.2 - 11.0	11.2 - 12.1	12.2 - 13.2
50-59	4.8	5.5	6.7 - 7.7	7.7 - 8.8	8.6 - 9.9	9.6 - 11.0	10.6 - 12.1	11.5 - 13.2
60-69	4.6	5.0	6.4 - 7.0	7.4 - 8.0	8.3 - 9.0	9.2 - 10.0	10.1 - 11.0	11.0 - 12.0
70-79	4.3	5.0	6.0 - 7.0	6.9 - 8.0	7.7 - 9.0	8.6 - 10.0	9.5 - 11.0	10.3 - 12.0

[1]Based on lowest and highest median REE (see Appendix 8).

The ranges in kcal/d of AR for energy for adults are tabled in Appendix 12A.

5.3.2. Infants

5.3.2.1. Total energy expenditure (TEE)

Published mean data on the TEE of infants living in developed and developing countries showed that TEE increases linearly with age, and, standardised by body mass, ranged from 255 to 393 kJ/kg (61-94 kcal/kg) per day (Butte, 2005). TEE of breast-fed infants was shown to be lower than that of formula-fed infants (Butte et al., 1990; Butte et al., 2000a; Davies et al., 1990; Jiang et al., 1998), however differences in TEE between feeding groups diminished beyond the first year of life (Butte et al., 2000a).

Because of the differences described above between breast-fed and formula-fed infants, separate regression equations for TEE as a function of body mass were obtained for these two groups (Butte, 2005).

According to Butte (2005), for breast-fed infants TEE can be predicted as follows:

TEE (MJ/d) = -0.635 + 0.388 kg; n = 195, r=0.87, s.e.e. = 0.453 MJ/d
TEE (kcal/d) = -152.0 + 92.8 kg; s.e.e. = 108 kcal/d
(n = number of observations; s.e.e. = standard error of estimate)

The Panel considers that the data on which the equation for formula-fed infants is based may no longer be appropriate because of recent significant changes in the composition of infant formula (e.g. a protein to energy ratio closer to human milk), and therefore decided to apply the equation for breast-fed infants when calculating TEE of infants.

5.3.2.2. Energy deposition in new tissue

TEE measured using the DLW method includes the energy expended in tissue synthesis, but not the energy deposited in growing tissues. Therefore, the latter should be added when calculating the energy reference values for infants. Energy deposited in new tissue was estimated from a multi-component body composition model (total body water, total body potassium and bone mineral content) (Butte et al., 2000b) based on a modified version of Fomon's term infant reference (Fomon et al., 1982) describing changes in body composition during growth. Estimates of protein and fat gain over three-month periods were used to predict energy accrued per g of gain in body mass (Table 6).

Table 6: Energy content of tissue deposition during the second half of infancy (Butte et al., 2000b; Butte, 2005; FAO/WHO/UNU, 2004)

Age interval (months)	Protein gain (g/d)	Fat mass gain (g/d)	Gain in body mass (g/d)	Energy deposited in growing tissues[1] (kJ/g)
Boys				
6-9	2.3	0.5	11.8	6.2
9-12	1.6	1.7	9.1	11.4
Girls				
6-9	2.0	0.8	10.6	7.4
9-12	1.8	1.1	8.7	9.8

[1]Taking into account that 1 g protein = 23.6 kJ; 1 g fat = 38.7 kJ

The estimates of energy deposited in new tissue are applied to the gain in body mass observed in the WHO Growth Standards for infants (2006) to estimate rates of energy deposition at monthly intervals. These predictions of energy deposited during growth derive from a relatively small study by Butte et al. (2000b) which was validated against other data sets (Butte, 2005). The Panel notes that the evolution of body mass and composition studied by Butte (2005), especially regarding gains in fat mass and fat-free mass during the first year of life, differs from other studies (de Bruin et al., 1998; Fields et al., 2011; Fomon et al., 1982). Since the impact on energy requirements was only marginal, the Panel decided to use the values proposed by Butte in line with FAO/WHO/UNU (2004) and SACN (2011). It is assumed that these values for the energy deposited in new tissue are appropriate for infants growing according to the WHO body mass velocity values, even though in the original study (Butte et al., 2000b) the pattern of breastfeeding followed was not fully described and the growth of infants did not fully reflect the WHO growth trajectory (WHO Multicentre Growth Reference Study Group, 2006).

5.3.3. Children

As for adults, the application of the factorial method for estimating TEE seems the most suitable for children as the advantages mentioned previously make it an approach well-fitted for the European context. Moreover, this approach allows estimating AR for energy for children and adolescents based on the recently obtained reference body masses and heights for EU children (van Buuren et al., 2012) (Table 7).

Table 7: Median body heights and body masses from harmonised growth curves for height and body mass of children in the EU (van Buuren et al., 2012)

Age (years)	Median body height (m)		Median body mass (kg)	
	Boys	**Girls**	**Boys**	**Girls**
1	0.76	0.75	10.2	9.5
2	0.88	0.87	12.7	12.1
3	0.97	0.96	14.7	14.2
4	1.04	1.03	17.0	16.4
5	1.11	1.10	19.2	18.7
6	1.17	1.16	21.5	21.1
7	1.23	1.22	24.3	23.8
8	1.30	1.28	27.4	26.8
9	1.35	1.34	30.6	30.0
10	1.40	1.40	33.8	33.7
11	1.45	1.46	37.3	37.9
12	1.51	1.52	41.5	42.6
13	1.58	1.58	46.7	47.5
14	1.65	1.61	52.7	51.6
15	1.71	1.63	59.0	54.6
16	1.75	1.64	64.1	56.4
17	1.77	1.64	67.5	57.4

5.3.3.1. Calculation of resting energy expenditure (REE)

From the available prediction equations for REE of children, those of Schofield et al. (1985) and Henry (2005) (Appendix 10) were derived from a large number of subjects covering the age range from 0 to 18 years and therefore – for comparison – are both used to calculate REE for estimating TEE by the factorial method. For the ages 1 to 17 years, the 50th percentiles of recently calculated reference body masses and heights for children in the EU (van Buuren et al., 2012) were used in the equations to calculate the REE (for details of the database and computation of reference body heights and body masses for infants and children see Appendix 11). Because the equations of Schofield et al. (1985) and Henry (2005) have overlapping age bands (0-3, 3-10, 10-18 years) the choice of equation is ambiguous at the age boundaries. Following the approach of SACN (2011) and the observation that the transition of the predicted values for the three age bands is smoother, the REE equation for 3-10 year-olds is used for the 3 year-olds, and the equation for 10-18 year-olds is used for those aged 10 years. The results reveal that REE calculated with these two equations are very similar and differ at most by 0.3 MJ/d in some age and sex groups (Table 8).

5.3.3.2. Selection of physical activity level (PAL) values

PAL values for children and adolescents were derived from measurements of TEE and REE. These values vary considerably according to lifestyle, geographic habitat and socioeconomic conditions, and inter-individual coefficients of variability as high as ± 34 % (Torun, 2001) have been reported. As indicated in the FAO/WHO/UNU report (2004), most studies were carried out on random or convenient samples, and therefore may not have captured the full range of potential physical activity.

SACN (2011) derived PAL values from a data set of all published DLW studies in children aged over one year including those studies assembled by Torun (2005) and other studies published up until 2006. Among the studies, seven were from Sweden, six from the UK and two from the Netherlands. The analysis revealed no influence of sex but an increase in PAL values with age. From an early age, however, there was a wide range of mean PAL values so that variation in PAL at any age was much greater than variation with age itself. Nevertheless, three age groups were identified within which the distribution of PAL values could be observed: 1-3 years, >3-<10 years and 10-18 years. These age ranges also correspond to the age ranges for which REE prediction equations have been generated by both Schofield et al. (1985) and Henry (2005).

As for adults, SACN (2011) calculated the AR for children using the median (PALs 1.39, 1.57 and 1.73 for ages 1-3, >3-<10 and 10-18 years, respectively), 25th (PALs 1.35, 1.42 and 1.66 for ages 1-3, >3-<10 and 10-18 years, respectively) and 75th (PALs 1.43, 1.69 and 1.85 for ages 1-3, >3-<10 and 10-18 years, respectively) percentile PAL values.

The Panel decided to rely on these results for defining the ranges of PAL values in children, for the reasons mentioned already in Section 5.3.1.2., and not to use the observed median and centile PAL values but, analogously to adults, to apply PAL values of equal steps within the observed ranges of PALs in the respective age groups for computing AR for energy. Thus, PAL values applied for estimating AR are as follows: 1.4 and 1.6 for the age group 1 to 3 years; 1.4, 1.6, 1.8, 2.0 and 2.2 for the age group >3 to <10 years; and 1.4, 1.6, 1.8, 2.0, 2.2 and 2.4 for the age group 10 to 18 years as (Table 8).

5.3.3.3. Energy expenditure of children and adolescents for growth

Energy needs for growth have two components: 1) the energy used to synthesise growing tissues and 2) the energy deposited in those tissues.

Energy spent in tissue synthesis is part of TEE. Due to the marked fall of deposited energy during the first year of life, the deposited energy accounts for only a relatively small proportion (< 2 %) of the total energy needs of children at all ages after the first year of life (see Section 2.3.3.).

The composition of newly accrued tissue mass during growth was based on measurements at one and two years of age (Butte et al., 2000a; Butte et al., 2000b; Butte, 2001). Assuming that the composition of normally growing tissues does not change much between the end of infancy and the onset of puberty, the average amount of energy deposited in growing tissues is about 8.6 kJ (2 kcal) per g of gain in body mass (Butte et al., 2000b; Butte, 2001; Torun, 2005). Even if this amount of energy was over- or underestimated by 50 %, it would only produce an error of about ± 1 % in the calculations of energy requirements in childhood and adolescence. In the report by FAO/WHO/UNU (2004), the energy deposited in growing tissues was estimated by multiplying the mean daily body mass gain at each year of age between 1 and 17 years by the average energy deposited in growing tissues. It was estimated that the amount of energy deposited is covered by an average increase of PAL of 1 % (FAO/WHO/UNU, 2004; James and Schofield, 1990).

5.3.3.4. Ranges of Average Requirement (AR) for energy for children and adolescents

Estimated AR of children and adolescents in the EU, based on the factorial method using median REE calculated as described above (Section 5.3.3.1.) and PAL values of 1.4 through 2.4 in steps of 0.2 increments, are presented in Table 8. The figures illustrate the variability in AR among children and adolescents in the EU depending on age, sex and PAL. The figures also reveal that estimated AR based on REE values calculated with the two equations are very similar and differ only in some age and sex groups by at most 0.6 MJ/d.

Table 8: Range of Average Requirement (AR) for energy for children and adolescents based on the factorial method using the equations of Schofield et al. (1985) and Henry (2005) for predicting REE, at different PAL values

Age (years)	REE[1] (Henry) (MJ/d)	REE[1] (Schofield et al.) MJ/d	Range of AR[2] at PAL = 1.4 (MJ/d)	Range of AR[2] at PAL = 1.6 (MJ/d)	Range of AR[2] at PAL = 1.8 (MJ/d)	Range of AR[2] at PAL = 2.0 (MJ/d)	Range of AR[2] at PAL = 2.2 (MJ/d)	Range of AR[2] at PAL = 2.4 (MJ/d)
Boys								
1	2.4	2.3	3.2 - 3.4	3.6 - 3.9				
2	3.1	3.0	4.2 - 4.4	4.8 - 5.0				
3	3.5	3.5	4.9 - 4.9	5.6 - 5.6				
4	3.7	3.7	5.2 - 5.3	6.0 - 6.0	6.7 - 6.8	7.5 - 7.5	8.2 - 8.3	
5	3.9	3.9	5.5 - 5.6	6.3 - 6.4	7.1 - 7.2	7.9 - 8.0	8.7 - 8.8	
6	4.2	4.1	5.8 - 5.9	6.7 - 6.7	7.5 - 7.6	8.4 - 8.4	9.2 - 9.3	
7	4.4	4.4	6.2 - 6.3	7.1 - 7.2	8.0 - 8.1	8.9 - 9.0	9.8 - 9.8	
8	4.7	4.7	6.6 - 6.7	7.6 - 7.6	8.5 - 8.6	9.5 - 9.5	10.4 - 10.5	
9	5.0	5.0	7.0 - 7.0	8.1 - 8.1	9.1 - 9.1	10.1 - 10.1	11.1 - 11.1	
10	5.0	5.3	7.1 - 7.4	8.1 - 8.5	9.1 - 9.6	10.1 - 10.6	11.1 - 11.7	12.1 - 12.7
11	5.3	5.5	7.5 - 7.8	8.5 - 8.9	9.6 - 10.0	10.7 - 11.2	11.8 - 12.3	12.8 - 13.4
12	5.6	5.8	8.0 - 8.3	9.1 - 9.4	10.2 - 10.6	11.4 - 11.8	12.5 - 13.0	13.6 - 14.2
13	6.0	6.2	8.5 - 8.8	9.8 - 10.1	11.0 - 11.3	12.2 - 12.6	13.4 - 13.9	14.6 - 15.1
14	6.5	6.7	9.2 - 9.5	10.5 - 10.8	11.8 - 12.2	13.1 - 13.5	14.5 - 14.9	15.8 - 16.2
15	7.0	7.1	9.9 - 10.1	11.3 - 11.6	12.7 - 13.0	14.1 - 14.4	15.5 - 15.9	16.9 - 17.3
16	7.4	7.5	10.4 - 10.6	11.9 - 12.2	13.4 - 13.7	14.9 - 15.2	16.4 - 16.7	17.9 – 18.2
17	7.6	7.8	10.8 - 11.0	12.3 - 12.5	13.8 - 14.1	15.4 - 15.7	16.9 - 17.3	18.4 – 18.8
Girls								
1	2.2	2.1	3.0 - 3.1	3.4 - 3.6				
2	2.9	2.8	4.0 - 4.1	4.5 - 4.7				
3	3.2	3.2	4.5 - 4.6	5.2 - 5.2				
4	3.5	3.4	4.8 - 4.9	5.5 - 5.6	6.2 - 6.3	6.9 - 7.0	7.6 - 7.7	
5	3.7	3.6	5.1 - 5.2	5.9 - 5.9	6.6 - 6.7	7.3 - 7.4	8.0 - 8.1	
6	3.9	3.8	5.4 - 5.5	6.2 - 6.3	7.0 - 7.1	7.7 - 7.8	8.5 - 8.6	
7	4.1	4.1	5.8 - 5.8	6.6 - 6.7	7.4 - 7.5	8.2 - 8.3	9.0 - 9.2	
8	4.4	4.3	6.1 - 6.2	7.0 - 7.1	7.9 - 7.9	8.7 - 8.8	9.6 - 9.7	
9	4.6	4.6	6.5 - 6.6	7.4 - 7.5	8.3 - 8.4	9.3 - 9.4	10.2 - 10.3	
10	4.7	4.7	6.7 - 6.7	7.6 - 7.7	8.6 - 8.6	9.5 - 9.6	10.5 - 10.5	11.4 – 11.5
11	4.9	5.0	7.0 - 7.1	8.0 - 8.1	9.0 - 9.1	10.0 - 10.1	11.0 - 11.1	12.0 – 12.1
12	5.2	5.3	7.3 - 7.5	8.4 - 8.6	9.4 - 9.6	10.5 - 10.7	11.5 - 11.8	12.6 – 12.8
13	5.4	5.6	7.7 - 7.9	8.8 - 9.0	9.9 - 10.1	11.0 - 11.2	12.1 - 12.4	13.2 – 13.5
14	5.6	5.8	8.0 - 8.2	9.1 - 9.3	10.2 - 10.5	11.4 - 11.7	12.5 - 12.8	13.7 – 14.0
15	5.8	5.9	8.2 - 8.4	9.3 - 9.6	10.5 - 10.8	11.7 - 12.0	12.8 - 13.2	14.0 – 14.4
16	5.9	6.0	8.3 - 8.5	9.5 - 9.7	10.6 - 10.9	11.8 - 12.1	13.0 - 13.3	14.2 – 14.5
17	5.9	6.0	8.3 - 8.6	9.5 - 9.8	10.7 - 11.0	11.9 - 12.2	13.1 - 13.4	14.3 – 14.7

[1] REE, resting energy expenditure computed from Henry and Schofield et al. equations (see Appendix 10); PAL, physical activity level

[2] Based on REE predicted with both equations, and taking into account a coefficient of 1.01 for growth.

The Range of Average Requirements (AR) for energy for children and adolescents based on the factorial method using the equations of Schofield et al. (1985) and Henry (2005) for predicting REE, at different PAL values expressed in kcal/d, is tabled in Appendix 12B.

5.3.4. Pregnant women

The additional energy requirement for pregnancy arises from increases in maternal and foeto-placental tissue mass, the rise in energy expenditure attributable to increased REE (see Section 2.3.4.) and changes in physical activity. TEF has been shown to be unchanged (Bronstein et al., 1995; Nagy and King, 1984; Spaaij et al., 1994b) or lower (Schutz et al., 1988) than for non-pregnant women, and therefore is not considered in the determination of the additional AR for energy for pregnancy.

5.3.4.1. Energy requirement for the increase in tissue mass during pregnancy

Based on the findings that gestational increases in body mass between 10 to 14 kg were associated with optimal maternal and foetal health outcomes (WHO, 1995a) (see Section 5.1.3.), in this Opinion, assuming a pre-pregnancy BMI within the recommended range, a mean gestational increase in body mass of 12 kg is taken as a basis for the calculation of the energy requirement for the increase in tissue mass.

The corresponding protein and fat gains associated with a mean body mass gain of 12 kg (range 10 to 14 kg) observed in the WHO collaborative study would be 597 g (range 497 to 696 g) and 3.7 kg (range 3.1 to 4.4 kg) respectively (FAO/WHO/UNU, 2004). Based on an energy value of 23.6 kJ/g (5.65 kcal/g) for protein deposited, and 38.7 kJ/g (9.25 kcal/g) for fat deposited, this would result in an energy storage of 14.1 MJ (3,370 kcal) for protein and of 144.8 MJ (34,600 kcal) for fat (Table 9).

The accretion of tissue mass is not distributed equally throughout the gestational period. The deposition of protein occurs primarily in the second (20 %) and third trimesters (80 %). Assuming that the rate of fat deposition follows the same pattern as the rate of gestational body mass gain, 11 %, 47 % and 42 % of fat is deposited in the first, second and third trimesters, respectively (IoM, 1990). Accordingly, the daily requirement of energy for protein and fat deposition is estimated as 0 and 202 kJ (0 and 48 kcal), 30 and 732 kJ (7 and 175 kcal), and 121 and 654 kJ (29 and 156 kcal) throughout the first, second and third trimesters, respectively (FAO/WHO/UNU, 2004).

5.3.4.2. Calculation of additional AR for energy for tissue deposition in pregnancy

As discussed in Section 2.3.4., on average EEPA is not significantly increased during pregnancy. Thus, apart from the energy stored in newly synthesised tissues, the increase in TEE during pregnancy is mainly due to the increase in REE. The cumulative increment of TEE as estimated with the DLW technique was 161.4 MJ (38,560 kcal). When subtracting from this value the energy estimated for the efficiency of energy utilisation of 15.9 MJ (3,800 kcal), which is included in the measurement of TEE by DLW, the remaining cumulative TEE of 145.5 MJ (34,760 kcal) is nearly equal to the estimated cumulative increase of REE (147.8 MJ (35,130 kcal), see Section 2.3.4.).

Table 9 reports on the additional energy expenditure during pregnancy.

Table 9: Additional energy expenditure of pregnancy in women with an average gestational increase in body mass of 12 kg[1] (adapted from FAO/WHO/UNU (2004))

	A. Rates of tissue deposition			
	1st trimester g/d	**2nd trimester g/d**	**3rd trimester g/d**	**Total deposition g/280 d**
Body mass gain	17	60	54	12,000
Protein deposition[2]	0	1.3	5.1	597
Fat deposition[2]	5.2	18.9	16.9	3,741

	B. Additional energy expenditure of pregnancy estimated from the increment in TEE and energy deposition				
	1st trimester kJ/d	**2nd trimester kJ/d**	**3rd trimester kJ/d**	**Energy expenditure during whole pregnancy MJ**	**kcal**
Protein deposition[2]	0	30	121	14.1	3,370
Fat deposition[2]	202	732	654	144.8	34,600
Total energy expenditure	85	350	1,300	161.4	38,560
Total energy expenditure plus energy content of protein and fat deposited	287	1,112	2,075	320.2	76,530

[1] Calculated as suggested by Butte and King (2002). Increase in body mass and tissue deposition in first trimester computed from last menstrual period (i.e. an interval of 79 days). Second and third trimesters computed as 280/3 = 93 days each.

[2] Protein and fat deposition estimated from longitudinal studies of body composition during pregnancy, and an energy value of 23.6 kJ (5.65 kcal)/g protein deposited, and 38.7 kJ (9.25 kcal)/g fat deposited.

5.3.5. Lactating women

DRVs for energy during lactation are estimated from TEE, milk energy output, and energy mobilisation from tissue stores that have been accumulated during pregnancy. Compared with non-pregnant, non-lactating women, there are no significant changes in REE, efficiency in work performance, or TEE (Butte and King, 2002), and in most societies women resume their usual level of physical activity in the first month *post partum* or shortly thereafter (Goldberg et al., 1991; Panter-Brick, 1993; Roberts et al., 1982; Tuazon et al., 1987; van Raaij et al., 1990).

TEE of lactating women can be calculated either by the factorial method as described above for non-pregnant and non-lactating women, or from DLW measurements. TEEs of lactating women have been measured by the DLW method in five studies (Butte et al., 2001; Forsum et al., 1992; Goldberg et al., 1991; Kopp-Hoolihan et al., 1999; Lovelady et al., 1993). Measurements were performed at various stages of lactation (one to six months); however, there are several potential sources of error using the DLW method in lactation studies, which may be attributed to isotope exchange and sequestration that occurs during the *de novo* synthesis of milk, fat and lactose, and to increased water flux into milk (Butte et al., 2001). Underestimation of carbon dioxide by 1.0 to 1.3 % may theoretically occur due to the export of exchangeable hydrogen bound to solids in milk (IDECG, 1990). This underestimation may increase to 1.5 to 3.4 % due to ^{2}H sequestration. Furthermore, the number of subjects in these studies was rather small (9 to 24). Therefore, in this Opinion, the Panel based the estimation of the additional AR for energy during lactation on the factorial method.

Mean milk intakes of infants through six months *post partum* measured by the test-weighing technique were 769 g/d for women exclusively breastfeeding (Butte and King, 2002). Correction of the mean milk intakes for the infant's insensible water loss (assumed to be equal to 5 %) gives a mean milk secretion over the first six months *post partum* of 807 g/d (FAO/WHO/UNU, 2004) for exclusively breastfeeding women.

In well-nourished women it has been estimated that on average the equivalent of 0.72 MJ/d of tissue stores may be utilised to support lactation during the first six months *post partum* (Butte and King, 2002), based on a rate of body mass loss of 0.8 kg per month (Butte and Hopkinson, 1998). This will vary depending on the amount of fat deposited during pregnancy, and on the lactation pattern and duration.

During the second half of infancy and the second year of life, volumes of breast milk intake are highly variable and depend on energy intake from complementary foods (FAO/WHO/UNU, 2004). In one study in which up to 12 infants from the US were still breast-fed during the second half of infancy, breast milk intakes had a range of 486-963 mL/d at seven months, 288-1006 mL/d at eight months, 242-889 mL/d at nine months, 143-896 mL/d at 10 months, 132-861 mL/d at 11 months and 73-772 mL/d at 12 months (Neville et al., 1988). In another study with 40 children from an industrialised country, mean breast milk intake in the second year of life (12-23 months) was 448 ± 251 g/d (WHO, 1998).

6. Key data on which to base Dietary Reference Values (DRVs)

The Panel decided to define only one DRV for energy, namely the AR, and to use the factorial method based on REE x PAL to obtain the average energy requirements for adults, children and adolescents. For infants, TEE is derived by regression equations based on DLW measurements. The additional energy requirements associated with growth during infancy, childhood and adolescence, and with pregnancy, are accounted for by estimates of the energy content of the newly-accrued tissue mass, as well as of the energy for its synthesis. For the additional energy requirement during lactation, milk energy output and energy mobilisation from tissue stores accumulated during pregnancy have been taken into account. As explained in Section 5, different equations and/or databases could be used, and this would lead to a range of ARs for various situations (see Tables 5 and 8). However, for ease of use, the Panel decided to propose only one AR for a defined age and sex group with a healthy body mass and for PAL values selected to approximate qualitatively defined situations (low active, moderately active, active and very active).

6.1. Adults

In this Opinion, the AR for energy for adults is based on predicted REE and PAL (see Section 5.3.1).

6.1.1. Calculation of resting energy expenditure (REE)

Although several predictive equations may be appropriate for estimating REE of various populations (as outlined in Sections 2.4. and 5.3.1.), for practical reasons the Panel decided to calculate REE as a function of age, sex, body mass and height by means of only one set of equations, namely those of Henry (2005). These equations were chosen because, at present, the underlying database is the most comprehensive as regards number of subjects, their nationalities and age groups. As described in Section 5.3.1.1., measured heights (obtained in 13 nationally representative surveys of adults in 13 EU countries) and corresponding body masses to yield a BMI of 22 kg/m^2 were used to calculate the REE (see Table 11). It is noted that there is a lack of anthropometric data from EU countries for age groups from 80 years onwards. Therefore, it was decided not to calculate AR for adults ≥ 80 years.

6.1.2. Derivation of physical activity level (PAL) values

From the range of observed PAL values, the Panel decided to use PAL values of 1.4, 1.6, 1.8 and 2.0 to reflect low active, moderately active, active and very active lifestyles, respectively, and proposes to apply these PAL values in the factorial method to determine ARs for energy (Table 11). However, the Panel notes that for population groups which are highly active, PAL values above 2.0 may be more appropriate (see Section 5.3.1.2., Table 5).

Available data indicate that it is difficult to generalise about the energy requirements of older adults (see Section 5.1.4.). However, in advanced age with reduced mobility, it can be assumed that PAL values are likely to be lower than in younger adults.

6.2. Infants

Exclusive breastfeeding to the age of about six months with continued breastfeeding as part of a progressively varied diet after six months is nutritionally adequate for most healthy infants born at term (EFSA Panel on Dietetic Products Nutrition and Allergies (NDA), 2009). For infants during the first half year of life (0-6 months of age), energy requirements are considered to be equal to the supply from human milk.

The Panel decided to use the equation for estimation of TEE derived from data of breast-fed infants (see 5.3.2.1.). Energy requirements during infancy were estimated from TEE measured by the DLW method in healthy, breast-fed, non-stunted infants born at term with adequate body mass, plus the energy needs for growth (Table 10). The WHO Growth Standard body masses (2006) were used to derive the AR for energy for infants growing along the trajectory of the WHO Growth standard. Estimates of energy deposition were based on measured protein and fat gains (see 5.3.2.2.).

Table 10: Derivation of the Average Requirement (AR) for energy for infants aged 7-11 months

Age (months)	Body mass (kg)[1]	Gain in body mass (g/d)[2]	Energy deposition (kJ/g)[3]	Energy deposition (kJ/d)[4]	TEE (kJ/d)[5]	AR (kJ/d)[6]	AR (kJ/kg per day)
Boys							
7	8.3	11.9	6.2	73.8	2,585	2,659	320
8	8.6	10.5	6.2	65.3	2,702	2,767	322
9	8.9	9.5	6.2	58.9	2,818	2,877	323
10	9.2	8.6	11.4	98.4	2,935	3,033	330
11	9.4	8.1	11.4	92.3	3,012	3,105	330
Girls							
7	7.6	11.5	7.4	84.9	2,314	2,399	316
8	7.9	10.4	7.4	76.7	2,430	2,507	317
9	8.2	9.1	7.4	67.3	2,547	2,614	319
10	8.5	8.2	9.8	80.0	2,663	2,743	323
11	8.7	7.8	9.8	76.1	2,741	2,817	324

[1] 50^{th} percentile of WHO Growth Standards; [2] Calculation from 1-month body mass increments from 50^{th} percentile of WHO Growth Standards, assuming that 1 month = 30 days; [3] see Table 6; [4] Body mass gain × energy accrued in normal growth; [5] Total Energy Expenditure (TEE) (MJ/d) = – 0.635 + 0.388 body mass (kg); [6] AR = TEE + energy deposition.

6.3. Children and adolescents

In this Opinion, ARs for energy for children and adolescents are based on predicted REE and PAL adjusted for growth.

6.3.1. Calculation of resting energy expenditure (REE)

Although, in principle, both the equations of Schofield et al. (1985) and Henry (2005) are considered as eligible for the estimation of REE for children and adolescents, for practical reasons and because the results obtained with these equations are very similar, only the equation of Henry (2005) is applied for the estimation of REE values to calculate ARs for energy for children and adolescents as described in Section 5.3.3.1. The Henry equations were chosen because their database comprises more subjects than the one underlying the Schofield equations. For the calculation, the median reference body masses and heights of children in EU countries (van Buuren et al., 2012) are used.

6.3.2. Derivation of physical activity level (PAL) values

From the range of observed PAL values in children and adolescents (see Section 5.3.3.2. and Table 8), the Panel proposes to use the following PAL values: 1.4 for the age group 1 to 3 years; 1.4, 1.6 and 1.8 for the age group >3 to <10 years; and 1.6, 1.8 and 2.0 for the age group 10 to 18 years (Table 13).

In this Opinion, energy expenditure for growth is accounted for by a 1 % increase of PAL values for each age group.

6.4. Pregnancy

The extra amount of energy required during pregnancy is calculated using the cumulative increment in TEE plus the energy deposited as protein and fat (see 5.3.4.). Based on these data, the average extra energy requirement for pregnancy is 320 MJ (76,530 kcal) divided into approximately 0.3 MJ/d, 1.1 MJ/d and 2.1 MJ/d (70 kcal/d, 260 kcal/d and 500 kcal/d) during the first, second and third trimesters, respectively (Tables 9 and 14).

There may be a large variation in the requirements for energy between individual pregnant women. A high variability is seen in the rates of gestational increase in body mass and energy expenditure of pregnant women depending on differences in pre-pregnant body mass and composition, lifestyle and underlying nutritional status. The coefficient of variability of the cumulative increase in REE was 16 % between studies, but the variability between women in each study was higher, namely 45 to 70 % in many cases (WHO/FAO/UNU, 2004). This variability should be taken into account when using the AR for additional energy intake during pregnancy on an individual basis.

6.5. Lactation

For exclusive breastfeeding during the first six months of life, the mean energy expenditure of lactation over the six month period is 2.8 MJ/d (675 kcal/d) based on a mean milk production of 807 g/d, an energy density of milk of 2.8 kJ/g (0.67 kcal/g), and an energetic efficiency of 80 %. Energy mobilisation from tissues in the order of 0.72 MJ/d (172 kcal/d) (Butte and King, 2002) may contribute to this energy expenditure and reduce the additional energy requirement during lactation to 2.1 MJ/d (500 kcal/d) over pre-pregnancy requirements.

During the second half of infancy and the second year of life, volumes of breast milk secreted are highly variable and depend on an infants' energy intake from complementary foods. Thus, the Panel decided not to propose an AR for additional energy intake for women lactating beyond the first six months after birth.

CONCLUSIONS

The Panel concludes that one Dietary Reference Value for energy, namely an Average Requirement, can be derived for adults, infants and children, and pregnant and lactating women. For infants, this is based on estimates of total energy expenditure determined with doubly labelled water studies, whereas for children and adults total energy expenditure is determined factorially from estimates of resting energy expenditure using the predictive equations of Henry (2005) and the energy needed for various levels of physical activity. For pregnant and lactating women, the additional energy needed for the deposition of newly formed tissue, and for milk output, was derived from data acquired with the doubly labelled water method, or on factorial estimates, respectively. Summary tables with the proposed Average Requirement expressed as kcal/d can be found in Appendix 13.

For the user, before applying these values, there is a need to specify the objective (such as dietary assessment (for groups or individuals), dietary planning (for groups or individuals specifying also the goal for body mass: maintenance, increase, decrease), labelling dietary reference values, development of food-based dietary guidelines) and a need to define the target population (homogeneous, heterogeneous, in relation to age, sex, ethnicity, physical activity, body mass) and to carefully characterise it. The detailed information provided in Section 5 should constitute a help to perform the adaptation of these values to specific objectives and populations/individuals.

Table 11: Summary of Average Requirement (AR) for energy for adults

Age (years)	REE[1] (MJ/d)	AR at PAL = 1.4 (MJ/d)	AR at PAL = 1.6 (MJ/d)	AR at PAL = 1.8 (MJ/d)	AR at PAL = 2.0 (MJ/d)
Men					
18-29	7.0	9.8	11.2	12.6	14.0
30-39	6.7	9.4	10.8	12.1	13.5
40-49	6.6	9.3	10.6	12.0	13.3
50-59	6.6	9.2	10.5	11.8	13.2
60-69	6.0	8.4	9.6	10.8	12.0
70-79	5.9	8.3	9.5	10.7	11.9
Women					
18-29	5.6	7.8	9.0	10.1	11.2
30-39	5.4	7.6	8.6	9.7	10.8
40-49	5.4	7.5	8.6	9.7	10.7
50-59	5.3	7.4	8.5	9.5	10.6
60-69	4.9	6.8	7.8	8.8	9.7
70-79	4.8	6.8	7.7	8.7	9.6

[1]REE, resting energy expenditure predicted with the equations of Henry (2005) using body mass and height. Because these have overlapping age bands (18-30 years, 30-60 years, ≥60 years) (see Appendix 1), the choice of equation is ambiguous at the age boundaries. The REE equations for 18-30 year-olds are used for adults aged 18-29 years, the equations for 30-60 year-olds are used for adults aged 30-39, 40-49 and 50-59 years, and the equations for ≥60 year-olds are used for adults aged 60-69 and 70-79 years.

Table 12: Summary of Average Requirement (AR) for energy for infants

Age	AR (MJ/d)		AR (MJ/kg body mass per day)	
	Boys	**Girls**	**Boys**	**Girls**
7 months	2.7	2.4	0.32	0.32
8 months	2.8	2.5	0.32	0.32
9 months	2.9	2.6	0.32	0.32
10 months	3.0	2.7	0.33	0.32
11 months	3.1	2.8	0.33	0.32

Table 13: Summary of Average Requirement (AR) for energy for children and adolescents

Age (years)	REE[1] (MJ/d)	AR[2] at PAL[3] = 1.4 (MJ/d)	AR[2] at PAL = 1.6 (MJ/d)	AR[2] at PAL = 1.8 (MJ/d)	AR[2] at PAL = 2.0 (MJ/d)
Boys					
1	2.4	3.4			
2	3.1	4.4			
3	3.5	4.9			
4	3.7	5.3	6.0	6.8	
5	3.9	5.6	6.4	7.2	
6	4.2	5.9	6.7	7.6	
7	4.4	6.3	7.2	8.1	
8	4.7	6.7	7.6	8.6	
9	5.0	7.0	8.1	9.1	
10	5.0		8.1	9.1	10.1
11	5.3		8.5	9.6	10.7
12	5.6		9.1	10.2	11.4
13	6.0		9.8	11.0	12.2
14	6.5		10.5	11.8	13.1
15	7.0		11.3	12.7	14.1
16	7.4		11.9	13.4	14.9
17	7.6		12.3	13.8	15.4
Girls					
1	2.2	3.1			
2	2.9	4.1			
3	3.2	4.6			
4	3.5	4.9	5.6	6.3	
5	3.7	5.2	5.9	6.7	
6	3.9	5.5	6.3	7.1	
7	4.1	5.8	6.7	7.5	
8	4.4	6.2	7.1	7.9	
9	4.6	6.6	7.5	8.4	
10	4.7		7.6	8.6	9.5
11	4.9		8.0	9.0	10.0
12	5.2		8.4	9.4	10.5
13	5.4		8.8	9.9	11.0
14	5.6		9.1	10.2	11.4
15	5.8		9.3	10.5	11.7
16	5.9		9.5	10.6	11.8
17	5.9		9.5	10.7	11.9

[1] REE, resting energy expenditure computed with the predictive equations of Henry (2005) using median heights and body masses of children in EU countries (van Buuren et al., 2012). Because these have overlapping age bands (0-3, 3-10, 10-18 years), the choice of equation is ambiguous at the age boundaries. The REE equation for 3-10 year-olds is used for the 3 year-olds and the equation for 10-18 year-olds is used for those aged 10 years.
[2] Taking into account a coefficient of 1.01 for growth.
[3] PAL, physical activity level.

Table 14: Summary of Average Requirement (AR) for energy for pregnant and lactating women (in addition to the AR for non-pregnant women)

	AR (MJ/d)
Pregnant women	
1st trimester	+ 0.3
2nd trimester	+ 1.1
3rd trimester	+ 2.1
Lactating women	
0-6 months *post partum*	+ 2.1

RECOMMENDATIONS FOR RESEARCH

The Panel suggests that differences in body composition (i.e. fat mass and fat-free mass) in relation to ethnicity should be explored further, and that predictive equations for resting energy expenditure should be adjusted to take this into account if needed. In the future, imaging techniques (such as whole body magnetic resonance imaging and echocardiography methods) and specific metabolic rates of major tissues and organs will allow the development of organ/tissue-based predictive equations for resting energy expenditure with a higher accuracy compared to predictive equations for resting energy expenditure based on body mass (index), fat mass and fat-free mass.

Since a precise estimate of the energy expenditure of physical activity is essential to give correct advice on the energy requirements of populations, the Panel stresses the need for the standardisation of the conditions for recording activity expenditure in order to fix reliable and reproducible values for the energy expenditure of physical activity taking into account sex and age.

For a more precise estimate of energy requirements at the European level, the Panel suggests generating and collecting more doubly labelled water data in conjunction with resting energy expenditure measurements in healthy adult and children populations in the EU representative of various geographical regions, including individuals of all ages with a broad range of physical activity levels corresponding to well-defined lifestyles.

In addition, the Panel suggests addressing diverging data with respect to body composition in infants, especially regarding gains in fat mass and fat-free mass during the first year of life.

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APPENDICES

APPENDIX 1: PREDICTIVE EQUATIONS FOR REE IN ADULTS

Author	Year	Number of subjects	Age range or mean	BMI range or mean	Remarks on large database	Sex	Statistics and cross validation	REE predictive equations
Harris and Benedict[a] (kcal/d) (United States)	(1919)	239	27 (M) 31 (F)	-	-	136 M 103 F	M: r=0.86, CL=±211 kcal[a] F: r=0.77, CL=±212 kcal	M: BM x 13.7516 + HTCM x 5.0033 – AGE x 6.755+66.473 F: BM x 9.5634 + HTCM x 1.8496 – AGE x 4.6756+655.0955
Schofield et al.[b] (body mass) (MJ/d)	(1985)	7,173, including children (about 11,000 values, including group mean values)	n=4,814 >18 y	mean BMIs of the 6 groups: between 21 and 24	n=3,388 Italians (47 %), n=615 tropical residents, n=322 Indians; 114 published studies, most European and North American subjects (Italian, closed circuit calorimetry)	4,809 M 2,364 F	M: r=0.65, se=0.64, n=2879 M: r=0.60, se=0.70, n=646 M: r=0.71, se=0.69, n=50 F: r=0.73, se=0.49, n=829 F: r=0.68, se=0.47, n=372 F: r=0.68, se=0.45, n=38	M: AGE 18-30 y: 0.063 x BM + 2.896 M: AGE 30-60 y: 0.048 x BM + 3.653 M: AGE ≥60 y: 0.049 x BM + 2.459 F: AGE 18-30 y: 0.062 x BM + 2.036 F: AGE 30-60 y: 0.034 x BM + 3.538 F: AGE ≥60 y: 0.038 x BM + 2.755
Schofield et al.[b] (body mass and height) (MJ/d)	(1985)	7,173, including children (about 11,000 values, including group mean values)	n=4,814 >18 y	mean BMIs of the 6 groups: between 21 and 24	n=3,388 Italians (47 %), n=615 tropical residents, n=322 Indians; 114 published studies, most European and North American subjects (Italian, closed circuit calorimetry)	4,809 M 2,364 F	M: r=0.65, se=0.64, n=2879 M: r=0.60, se=0.70, n=646 M: r=0.74, se=0.66, n=50 F: r=0.73, se=0.49, n=829 F: r=0.68, se=0.47, n=372 F: r=0.73, se=0.43, n=38	M: AGE 18-30 y: 0.063 x BM – 0.042 x HTM + 2.953 M: AGE 30-60 y: 0.048 x BM – 0.011 x HTM + 3.67 M: AGE ≥60 y: 0.038 x BM + 4.068 x HTM – 3.491 F: AGE 18-30 y: 0.057 x BM + 1.184 x HTM + 0.411 F: AGE 30-60 y: 0.034 x BM + 0.006 x HTM + 3.53 F: AGE ≥60 y: 0.033 x BM + 1.917 x HTM + 0.074
FAO[b] (body mass) (MJ/d)	(1985)	This report mentions that the equations are based on Schofield et al (1985); however, the figures in Schofield et al. (1985) differ slightly from those of the FAO, because additional data were included by the authors of that analysis after the FAO report was compiled.					M: r=0.65, SD=0.632 M: r=0.60, SD=0.686 M: r=0.79, SD=0.619 F: r=0.72, SD=0.506 F: r=0.70, SD=0.452 F: r=0.74, SD=0.452	M: AGE 18–30 y: 0.0640 x BM + 2.84 M: AGE 30–60 y: 0.0485 x BM + 3.67 M: AGE ≥60 y: 0.0565 x BM + 2.04 F: AGE 18–30 y: 0.0615 x BM + 2.08 F: AGE 30–60 y: 0.0364 x BM + 3.47 F: AGE ≥60 y: 0.0439 x BM + 2.49

Author	Year	Number of subjects	Age range or mean	BMI range or mean	Remarks on large database	Sex	Statistics and cross validation	REE predictive equations
FAO[b] (body mass and height) (MJ/d)	(1985)	This report mentions that the equations are based on Schofield et al (1985); however, the figures in Schofield et al. (1985) differ slightly from those of the FAO, because additional data were included by the authors of that analysis after the FAO report was compiled.					M: r=0.65, RSD=0.632 M: r=0.60, RSD=0.686 M: r=0.84, RSD=0.552 F: r=0.73, RSD=0.502 F: r=0.70, RSD=0.452 F: r=0.82, RSD=0.393	M: AGE 18–30 y: 0.0644 x BM – 0.1130 x HTM + 3.0 M: AGE 30–60 y: 0.0472 x BM + 0.0669 x HTM + 3.769 M: AGE ≥60 y: 0.0368 x BM + 4.7195 x HTM – 4.481 F: AGE 18–30 y: 0.0556 x BM + 1.3974 x HTM + 0.146 F: AGE 30–60 y: 0.0364 x BM – 0.1046 x HTM + 3.619 F: AGE ≥60 y: 0.0385 x BM + 2.6652 x HTM – 1.264
Owen et al. (kcal/d) (United States)	(1987) (M) (1986) (F)	104	18-82 y (M) 18-65 (F)	20.4-58.7 (M) 18.2-49.6 (F)	-	60 M (including 16 obese, BMI>30 kg/m^2) 44 F (including 16 obese, BMI>30 kg/m^2)	M: r=0.75 F: r=0.74	M: BM x 10.2 + 879 F: BM x 7.18 + 795
Mifflin et al. (kcal/d) (United States)	(1990)	498 (264 normal body mass, 234 obese)	19-78 y	17-42	-	251 M (129 normal body mass, 122 obese), 247 F (135 normal body mass, 112 obese)	R^2=0.71	9.99 x BM + 6.25 x HTCM – 4.92 x AGE + 166 x SEX - 161
De Lorenzo et al. (kJ/d) (Italy)	(2001)	320	18–59 y	Mean: about 27 (range: 18.6–40)	-	127 M, 193 F	M: R^2=0.597, s.e.e.=650 kJ/d F: R^2=0.597, s.e.e.=581 kJ/d	M: 53.284 x BM + 20.957 x HTCM – 23.859 x AGE + 487 F: 46.322 x BM + 15.744 x HTCM – 16.66 x AGE + 944
Müller et al.[b] (MJ/d) (Germany)	(2004)	2,528 (development of equation in sub-population 1: n=1,046)	5–91 y	Mean BMI: 27	-	1,027 M, 1,501 F (development: 388 M, 658 F)	Development: R^2=0.73, s.e.e.=0.83. Cross-validation in sub-population 2: n=1,059 (410 M, 649 F)[e], r=0.83	0.047 x BM – 0.01452 x AGE + 1.009 x SEX + 3.21
Müller et al.[b] (BMI[f], MJ/d) (Germany)	(2004)	2,528 (development of equation in sub-population 1: n=1,046)	5–91 y	Mean BMI: 27	-	1,027 M, 1,501 F (development: 388 M, 658 F)	Development: R^2=0.52, s.e.e.=0.79 (n=444, for BMI >18.5 to 25). Cross-validation in sub-population 2: r=0.72. Development: R^2=0.62, s.e.e.=0.77 (n=266, for BMI >25 to <30). Cross-validation in sub-population 2: r=0.79. Development: R^2=0.75, s.e.e.=0.91 (n=278, for BMI ≥30). Cross-validation in sub-population 2: r=0.84	BMI >18.5 to 25: 0.02219 x BM +0.02118 x HTCM – 0.01191 x AGE + 0.884 x SEX + 1.233 BMI >25 to <30: 0.04507 x BM - 0.01553 x AGE + 1.006 x SEX + 3.407 BMI ≥30: 0.05 x BM - 0.01586 x AGE + 1.103 x SEX + 2.924

Author	Year	Number of subjects	Age range or mean	BMI range or mean	Remarks on large database	Sex	Statistics and cross validation	REE predictive equations
Müller et al.[b] (FFM[d], MJ/d) (Germany)	(2004)	2,528 (development of equation in sub-population 1: n=1,046)	5–91 y	Mean BMI: 27	-	1,027 M, 1,501 F (development: 388 M, 658 F),	Development: R^2=0.71, s.e.e.=0.77. Cross-validation in sub-population 2: n=1,059 (410 M, 649 F)[e]: r=0.83	0.05192 x FFM + 0.04036 x FM + 0.869 x SEX - 0.01181 x AGE + 2.992
Müller et al.[b] (BMI[f] and FFM[d], MJ/d) (Germany)	(2004)	2,528 (development of equation in sub-population 1: n=1,046)	5–91 y	Mean BMI: 27	-	1,027 M, 1,501 F (development: 388 M, 658 F),	Development: R^2=0.54, s.e.e.=0.78, (n=444, for BMI > 18.5 to 25). Cross-validation in sub-population 2: r=0.75. Development: R^2=0.65, s.e.e=0.62 (n=266, for BMI >25 to <30). Cross-validation in sub-population 2: r=0.79 Development: R^2=0.70, s.e.e.=0.87 (n=278, for BMI ≥30). Cross-validation in sub-population 2: r=0.84.	BMI > 18.5 to 25: 0.0455 x FFM + 0.0278 x FM + 0.879 x SEX - 0.01291 x AGE + 3.634 BMI >25 to <30: 0.03776 x FFM + 0.03013 x FM + 0.93 x SEX - 0.01196 x AGE + 3.928 BMI ≥30: 0.05685 x FFM + 0.04022 x FM + 0.808 x SEX - 0.01402 x AGE + 2.818
Vander Weg et al. (Memphis equation) (kJ/d) (United States)	(2004)	471 women (development of equation in sub-population 1: 239 women)	18-39 y	Mean BMI: 25.2		471 women (205 African American, 266 European American)	Development: 239 women (97 African American, 142 European American); adjusted R^2: 0.51. Cross-validation in sub-population 2: 232 women (108 African American, 124 European American); adjusted R^2: 0.55 for African American, 0.31 for European American.	616.93 - 14.9 x AGE + 35.12 x BM + 19.83 x HTCM – 271.88 x ETHNICITY
Henry[b] (body mass) (MJ/d)	(2005)	10,552 *(10,502)* including children	-	-	166 separate investigations, only individual data points; all Italian, closed circuit data excluded; 4,018 subjects from the tropics included	5,794 M	M: r= 0.760, se=0.652; n=2,821	M: AGE 18–30 y: 0.0669 x BM + 2.28
							M: r=0.742, se=0.693; n=1,010	M: AGE 30–60 y: 0.0592 x BM + 2.48
							M: r=0.776, se=0.685; n=534	M: AGE ≥60 y: 0.0563 x BM + 2.15
							M: r=0.766, se=0.697; n=270	M: AGE 60-70 y: 0.0543 x BM + 2.37
							M: r=0.779, se=0.667; n=264	M: AGE ≥70 y: 0.0573 x BM + 2.01
(Oxford Database)						4,702 F *(4,708)*	F: r=0.700, se=0.564; n=1,664	F: AGE 18–30 y: 0.0546 x BM + 2.33
							F: r=0.690, se=0.581; n=1,023	F: AGE 30–60 y: 0.0407 x BM + 2.90
							F: r=0.786, se=0.485; n=334 *(340)*	F: AGE ≥60 y: 0.0424 x BM + 2.38
							F: r=0.796, se=0.476; n=185	F: AGE 60-70 y: 0.0429 x BM + 2.39
							F: r=0.746, se=0.518; n=155	F: AGE ≥70 y: 0.0417 x BM + 2.41

Author	Year	Number of subjects	Age range or mean	BMI range or mean	Remarks on large database	Sex	Statistics and cross validation	REE predictive equations
Henry[b] (body mass and height) (MJ/d) (Oxford database)	(2005)	10,552 *(10502?)* including children	-	-	166 separate investigations, only individual data points; all Italian closed circuit data excluded; 4,018 subjects from the tropics included.	5,794 M,	M: r=0.764, se=0.648; n=2,816	M: AGE 18–30 y: 0.0600 x BM + 1.31 x HTM + 0.473
							M: r=0.756, se= 0.678; n=1,006	M: AGE 30–60 y: 0.0476 x BM + 2.26 x HTM - 0.574
							M: r=0.789, se=0.668; n= 533	M: AGE ≥60 y: M: 0.0478 x BM + 2.26 x HTM - 1.07
						4,702 F	F: r=0.724, se=0.542; n=1,655	F: AGE 18–30 y: 0.0433 x BM + 2.57 x HTM - 1.18
							F: r=0.713, se=0.564; n=1,023	F: AGE 30–60 y: 0.0342 x BM + 2.10 x HTM - 0.0486
							F: r=0.805, se=0.472; n=324	F: AGE ≥60 y: 0.0356 x BM + 1.76 x HTM + 0.0448

CL, confidence limits; ETHNICITY (African American = 1, European American = 0); F, female; FFM, fat free mass (kg); FM, fat mass (kg); HTCM, height in cm; HTM, height in meter; M, male; r, correlation coefficient; SD, standard deviation; SEX (M=1, F=0); se, standard error; s.e.e., standard error of estimate; BM, body mass in kg.

[a] From: (Roza and Shizgal, 1984) (not the original publication)

[b] Equations are also available for children (FAO/WHO/UNU, 1985; Henry, 2005; Müller et al., 2004; Schofield et al., 1985).

[c] Equations are also available for BMI ≤18.5, either with body mass, age and sex, or with FFM and FM.

[d] Body composition method: bioimpedance analysis (different equations, multicenter study).

[e] Including n=482 (BMI >18.5-25), n=267 (BMI >25 to <30), n=261 (BMI ≥30).

[f] Equation also available for BMI ≤18.5.

[g] Figures given in Italics differ from those in the publication but are assumed to be as such after recalculation of the figures, as also stated in Ramirez-Zea (2005) for total number per sex.

2600 **APPENDIX 2A: POPULATION, METHODS AND PERIOD OF DIETARY ASSESSMENT IN CHILDREN AND ADOLESCENTS IN EUROPEAN COUNTRIES**

Country	Population	Dietary assessment method	Year of survey	Reference
Austria	Boys and girls aged 7-9 years	3-day record	2007-2008	(Elmadfa et al., 2009a; Elmadfa et al., 2009b)
	Boys and girls aged 10-14 years	3-day record	2007-2008	(Elmadfa et al., 2009a; Elmadfa et al., 2009b)
	Boys and girls aged 14-19 years	24-hour recall	2003-2004	(Elmadfa et al., 2009a; Elmadfa et al., 2009b). *Mainly from a large Viennese sample.*
Belgium	Boys and girls aged 2.5-3 years	3-day record	2002-2003	(Huybrechts and De Henauw, 2007). *Data collected in Flanders.*
	Boys and girls aged 4-6.5 years	3-day record	2002-2003	(Huybrechts and De Henauw, 2007). *Data collected in Flanders.*
	Boys and girls aged 13-15 years	7-day record	1997	(Matthys et al., 2003). *Data collected in the region of Ghent in Flanders.*
	Boys and girls aged 15-18 years	2 x 24-hour recall	2004	(De Vriese et al., 2006)
Bulgaria	Boys and girls aged 1-3 years	24-hour recall	1998	(Abrasheva et al., 1998)
	Boys and girls aged 3-6years	24-hour recall	1998	(Abrasheva et al., 1998)
	Boys and girls aged 6-10 years	24-hour recall	1998	(Abrasheva et al., 1998)
	Boys and girls aged 10-14 years	24-hour recall	1998	(Abrasheva et al., 1998)
	Boys and girls aged 14-18 years	24-hour recall	1998	(Abrasheva et al., 1998)
Czech Republic	Boys and girls aged 4-6 years	48-hour recall	2007	(Elmadfa et al., 2009b)
	Boys and girls aged 7-9 years	48-hour recall	2007	(Elmadfa et al., 2009b)
Denmark	Boys and girls aged 1-3 years	7-day record	1995	(Andersen et al., 1996)
	Boys and girls aged 4-5 years	7-day record	2003-2008	(Pedersen et al., 2010)
	Boys and girls aged 6-9 years	7-day record	2003-2008	(Pedersen et al., 2010)
	Boys and girls aged 10-13 years	7-day record	2003-2008	(Pedersen et al., 2010)
	Boys and girls aged 14-17 years	7-day record	2003-2008	(Pedersen et al., 2010)
Finland	Children aged 1 year	3-day record	2003-2005	(Kyttälä et al., 2008; Kyttälä et al., 2010)
	Children aged 2 years	3-day record	2003-2005	(Kyttälä et al., 2008; Kyttälä et al., 2010)
	Children aged 3 years	3 day record	2003-2005	(Kyttälä et al., 2008; Kyttälä et al., 2010)
	Children aged 4 years	3-day record	2003-2005	(Kyttälä et al., 2008; Kyttälä et al., 2010)
	Children aged 6 years	3-day record	2003-2005	(Kyttälä et al., 2008; Kyttälä et al., 2010)
France	Boys and girls aged 4-6 years	3x 24-hour recall	2006-2007	(Elmadfa et al., 2009b)
	Boys and girls aged 7-9 years	3x 24-hour recall	2006-2007	(Elmadfa et al., 2009b)
	Boys and girls aged 10-14 years	3x 24-hour recall	2006-2007	(Elmadfa et al., 2009b)
	Boys and girls aged 15-18 years	3x 24-hour recall	2006-2007	(Elmadfa et al., 2009b)

Country	Population	Dietary assessment method	Year of survey	Reference
Germany	Infants aged 12 months	3-day records	1989-2003	(Hilbig and Kersting, 2006).
	Children aged 18 months	3-day records	1989-2003	(Hilbig and Kersting, 2006).
	Children aged 2 years	3-day records	1989-2003	(Hilbig and Kersting, 2006).
	Children aged 3 years	3-day records	1989-2003	(Hilbig and Kersting, 2006).
	Boys and girls aged 6 years	3-day record	2006	(Elmadfa et al., 2009b; Mensink et al., 2007)
	Boys and girls aged 7-9 years	3-day record	2006	(Elmadfa et al., 2009b; Mensink et al., 2007)
	Boys and girls aged 10-11 years	3-day record	2006	(Elmadfa et al., 2009b; Mensink et al., 2007)
	Boys and girls aged 12 years	Dietary history (over the last 4 weeks)	2006	(Elmadfa et al., 2009b; Mensink et al., 2007)
	Boys and girls aged 13-14 years	Dietary history (over the last 4 weeks)	2006	(Elmadfa et al., 2009b; Mensink et al., 2007)
	Boys and girls aged 15-17 years	Dietary history (over the last 4 weeks)	2006	(Mensink et al., 2007)
Greece	Boys and girls aged 1-5 years	3-day record (weighed food records and 24 h recall or food diaries)	2003-2004	(Manios, 2006; Manios et al., 2008)
	Boys and girls aged 12-24 mo	3-day record (weighed food records and 24 h recall or food diaries)	2003-2004	(Manios, 2006; Manios et al., 2008)
	Boys and girls aged 25-36 mo	3-day record (weighed food records and 24 h recall or food diaries)	2003-2004	(Manios, 2006; Manios et al., 2008)
	Boys and girls aged 37-48 mo	3-day record (weighed food records and 24 h recall or food diaries)	2003-2004	(Manios, 2006; Manios et al., 2008)
	Boys and girls aged 49-60 mo	3-day record (weighed food records and 24 h recall or food diaries)	2003-2004	(Manios, 2006; Manios et al., 2008)
Hungary	Boys and girls aged 11-14 years	3-day record	2005-2006	(Biro et al., 2007). *Data collected in Budapest.*
Ireland	Boys and girls aged 5-8 years	7-day record	2003-2004	(IUNA (Irish Universities Nutrition Alliance), a)
	Boys and girls aged 9-12 years	7-day record	2003-2004	(IUNA (Irish Universities Nutrition Alliance), a)
	Boys and girls aged 13-14 years	7-day record	2005-2006	(IUNA (Irish Universities Nutrition Alliance), b)
	Boys and girls aged 15-17 years	7-day record	2005-2006	(IUNA (Irish Universities Nutrition Alliance), b)
Italy	Boys and girls 0-<3 years	Consecutive 3-day food records	2005-2006	(Sette et al., 2010)
	Boys and girls 3-<10 years	Consecutive 3-day food records	2005-2006	(Sette et al., 2010)
	Boys and girls 10-<18 years	Consecutive 3-day food records	2005-2006	(Sette et al., 2010)
Latvia	Boys and girls aged 7-16 years	2 non-consecutive 24-hour dietary recalls + food frequency questionnaire	2008	(Joffe et al., 2009)
The Netherlands	Infants aged 9 months	2-day record (independent days)	2002	(de Boer et al., 2006)
	Infants aged 12 months	2-day record (independent days)	2002	(de Boer et al., 2006)
	Children aged 18 months	2-day record (independent days)	2002	(de Boer et al., 2006)
	Boys and girls aged 2-3 years	2-day record (independent days)	2005-2006	(Ocké et al., 2008)
	Boys and girls aged 4-6 years	2-day record (independent days)	2005-2006	(Ocké et al., 2008)
	Boys and girls aged 7-8 years	2 non-consecutive 24-hour dietary recalls	2007-2010	(van Rossum et al., 2011)
	Boys and girls aged 9-13years	2 non-consecutive 24-hour dietary recalls	2007-2010	(van Rossum et al., 2011)
	Boys and girls aged 14-18 years	2 non-consecutive 24-hour dietary recalls	2007-2010	(van Rossum et al., 2011)
Norway	Children aged 2 years	Food Frequency Questionnaire	2007	(Kristiansen and Andersen, 2009)
	Boys and girls aged 4 years	4-day record	2000	(Elmadfa et al., 2009b)
	Boys and girls aged 9 years	4-day record	2000	(Elmadfa et al., 2009b)
	Boys and girls aged 13 years	4-day record	2000	(Elmadfa et al., 2009b)
	Boys and girls aged 16-19 years	Food Frequency Questionnaire	1997	(Johansson and Sovoll, 1999)

Country	Population	Dietary assessment method	Year of survey	Reference
Poland	Boys and girls aged 1-3 years	24-hour recall	2000	(Szponar et al., 2003)
	Boys and girls aged 4-6 years	24-hour recall	2000	(Szponar et al., 2003)
	Boys and girls aged 7-9 years	24-hour recall	2000	(Szponar et al., 2003)
	Boys and girls aged 10-12 years	24-hour recall	2000	(Szponar et al., 2003)
	Boys and girls aged 13-15 years	24-hour recall	2000	(Szponar et al., 2003)
	Boys and girls aged 16-18 years	24-hour recall	2000	(Szponar et al., 2003)
Portugal	Boys and girls aged 5-10 years	Food Frequency Questionnaire	2006-2007	(Moreira et al., 2010). *Data collected in Porto.*
Slovenia	Boys and girls aged 14-16 years	Food Frequency Questionnaire	2003-2005	(Kobe et al., 2011)
Spain	Boys and girls aged 10-14 years	2 non-consecutive 24-hour recalls	2002-2003	(Elmadfa et al., 2009b). *Data collected in Catalonia.*
	Boys and girls aged 15-18 years	2 non-consecutive 24-hour recalls	2002-2003	(Elmadfa et al., 2009b). *Data collected in Catalonia.*
Sweden	Boys and girls aged 4 years	4-day record	2003	(Enghardt-Barbieri et al., 2006)
	Boys and girls aged 8-9 years	4-day record	2003	(Enghardt-Barbieri et al., 2006)
	Boys and girls aged 11-12 years	4-day record	2003	(Enghardt-Barbieri et al., 2006)
United Kingdom	Boys and girls aged 1.5-3 years	4-day food diary	2008-2010	(Bates et al., 2011)
	Boys and girls aged 4-10 years	4-day food diary	2008-2010	(Bates et al., 2011)
	Boys and girls aged 11-18 years	4-day food diary	2008-2010	(Bates et al., 2011)

2601 mo: months

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APPENDIX 2B: ENERGY INTAKE OF CHILDREN AGED ~1-3 YEARS IN EUROPEAN COUNTRIES

Country	Age (years)	N	Energy (MJ/d) mean	SD	P50	P5 – P95	Energy (kcal/d) mean	SD	P50	P5 – P95
Infants and/or young children (both sexes)										
Bulgaria	1-3 years	154	5.9[1]	3.0[1]	5.4[1]		1,401	705	1,299	
Germany	12 mo	432[2,3]	0.35[4]	0.06[4]						
	18 mo	478[2]	0.33[4]	0.06[4]						
	2 years	458[2]	0.32[4]	0.05[4]						
	3 years	427[2]	0.31[4]	0.05[4]						
Italy	0-<3 years	52	4.7	1.8	4.4	1.9-8.0	1,113	419	1,057	457-1,905
The Netherlands	9 mo	333	4.1	0.7	4.0	3.2-5.0[5]				
	12 mo	306	4.5	0.7	4.4	3.7-5.4[5]				
	18 mo	302	4.9	0.8	4.8	4.0-5.9[5]				
United Kingdom	1.5-3 years	219	4.8	1.2	4.7	2.7-7.0[6]	1,127	280	1,113	649-1,678[6]
Young children										
Boys										
Belgium	2.5-3	102	6.5	1.1	6.5					
Denmark	1-3	129	6.9							
Finland	1[3]	257	3.9	0.7			938	158		
	2	112	4.6	1.0			1,107	234		
	3	236	5.4	1.0			1,279	236		
Greece	12-24 mo	100	5.4	0.9			1,277	211		
	25-36 mo	274	5.8	1.0			1,395	228		
	37-48 mo	488	6.0	1.0			1,442	237		
The Netherlands	2-3	327	5.8		5.7	4.2-7.5	1,375		1,363	1,000-1,792
Norway	2	829	5.9	1.5						
Poland	1-3	70	5.9	2.2	5.5		1,407	524	1,318	
Girls										
Belgium	2.5-3	95	5.8	0.9	5.7					
Denmark	1-3	149	6.4							
Finland	1[3]	198	3.6	0.6			863	132		
	2	118	4.5	0.9			1,077	213		
	3	235	5.0	1.0			1,211	234		
Greece	12-24 mo	107	5.2	0.8			1,247	179		
	25-36 mo	226	5.6	0.9			1,338	219		
	37-48 mo	434	5.8	1.0			1,379	237		
The Netherlands	2-3	313	5.5		5.4	4.1-7.2	1,308		1,288	971-1708
Norway	2	826	5.5	1.5						
Poland	1-3	48	5.4	1.6	5.3		1,283	378	1,277	

mo: months
[1]Calculated from values in kcal;
[2]Number of 3-day records;
[3]Breast-fed infants not included
[4]MJ/kg body mass (mean body mass of boys and girls, at 12 mo (whether breast-fed or not): 10.1 and 9.3 kg; 18 mo: 11.8 and 11.0 kg; 2 years: 13.2 and 12.3 kg; 3 years: 15.6 and 14.7 kg, respectively). Underreporters excluded.
[4]P10-P90
[5]P2.5-P97.5

APPENDIX 2C: ENERGY INTAKE OF CHILDREN AGED ~4-6 YEARS IN EUROPEAN COUNTRIES

Country	Age (years)	N	Energy (MJ/d)				Energy (kcal/d)			
			mean	*SD*	*P50*	*P5 – P95*	*mean*	*SD*	*P50*	*P5 – P95*
Boys										
Belgium	4-6.5	236	6.4	0.9	6.4					
Czech Republic	4-6	641	6.5	1.3						
Denmark	4-5	81	7.7	1.5	7.6	5.7-10.5				
Finland	4	307	5.8	1.1			1,388	258		
	6	364	6.7	1.2			1,599	278		
France	4-6	164	6.3	0.1						
Germany	6	106	7.2	1.4	7.3	4.8-9.8	1,712	332	1,738	1,145-2,341
Greece	49-60 mo	356	6.2	0.1			1,475	296		
The Netherlands	4-6	327	6.7		6.6	5.3-8.2	1,587		1,579	1,252-1,951
Norway	4	206	6.3	1.5						
Poland	4-6	82	7.9	2.4	7.5		1,890	562	1,800	
Sweden	4	302	6.5	1.2	6.5	4.5-8.8	1,556	298	1,546	1,086-2,097
United Kingdom	4-10	210	6.7	1.3	6.6	4.3-9.7[1]	1,591	314	1,573	1,021-2,301[1]
Girls										
Belgium	4-6.5	228	5.9	0.9	5.9					
Czech Republic	4-6	446	6.5	1.3						
Denmark	4-5	78	7.0	1.6	6.8	5.2-9.7				
Finland	4	247	5.5	1.0			1,302	233		
	6	349	6.0	1.1			1,431	256		
France	4-6	162	6.3	0.1						
Germany	6	102	6.3	1.3	6.2	3.8-8.7	1,511	320	1,471	912-2,071
Greece	49-60 mo	389	5.9	0.1			1,414	260		
The Netherlands	4-6	312	6.2		6.2	4.7-7.8	1,479		1,470	1,123-1,866
Norway	4	185	6.1	1.2						
Poland	4-6	84	7.1	2.4	7.0		1,698	582	1,663	
Sweden	4	288	6.1	1.2	6.1	4.2-7.9	1,454	289	1,450	1,000-1,895
United Kingdom	4-10	213	6.4	1.3	6.5	3.8-8.9[1]	1,519	314	1,531	900-2,114[1]
Both sexes										
Bulgaria	3-6	199	7.4[2]	3.1[2]	6.8[2]		1,759	735	1,628	
Italy	3-<10	193	8.0	2.0	8.0	4.8-11.5	1,914	488	1,906	1,138-2,750

[1]P2.5-P97.5
[2]Calculated from values in kcal.

APPENDIX 2D: ENERGY INTAKE OF CHILDREN AGED ~7-9 YEARS IN EUROPEAN COUNTRIES

Country	Age (years)	N	Energy (MJ/d)				Energy (kcal/d)			
			mean	*SD*	*P50*	*P5 – P95*	*mean*	*SD*	*P50*	*P5 – P95*
Boys										
Austria	7-9	146	6.9	1.9						
Czech Republic	7-9	940	7.6	2.8						
Denmark	6-9	172	8.8	2.2	8.4	6.2-12.7				
France	7-9	160	7.6	0.2						
Germany	7-9	321	7.8	1.6	7.8	5.5-10.6	1,867	371	1,850	1,312-2,514
Ireland	5-8	145	6.8	1.5	6.8	4.6-9.6	1,625	359	1,608	1,106-2,287
Latvia	7-16	295	8.2[1]				1,948			
The Netherlands	7-8	153			8.1	5.3-11.6			1,929	1,267-2,753
Norway	9	402	8.6	2.0						
Poland	7-9	101	9.1	2.9	9.1		2,184	695	2,167	
Portugal	5-10	985	9.7[1]	2.7[1]			2,327	647		
Sweden	8-9	444	8.1	1.8	8.0	5.5-11.2	1,927	423	1,901	1,311-2,682
Girls										
Austria	7-9	134	6.3	1.6						
Czech Republic	7-9	765	7.6	2.8						
Denmark	6-9	151	7.8	1.6	7.7	5.5-10.8				
France	7-9	144	6.9	0.2						
Germany	7-9	308	7.0	1.4	7.0	4.5-9.5	1,663	333	1,669	1,075-2,271
Ireland	5-8	151	6.4	1.2	6.2	4.6-8.4	1,517	278	1,467	1,105-1,985
Latvia	7-16	277	6.9[1]				1,660			
The Netherlands	7-8	151			8.4	5.9-11.3			2,011	1,409-2,706
Norway	9	408	7.7	2.0						
Poland	7-9	103	8.0	2.5	7.8		1,921	592	1,843	
Portugal	5-10	991	9.1[1]	2.5[1]			2,177	593		
Sweden	8-9	445	7.2	1.5	7.1	4.8-9.6	1,719	360	1,699	1,139-2,301
Both sexes										
Bulgaria	6-10	235	9.5[1]	3.8[1]	9.1[1]		2,277	900	2,179	

[1]Calculated from values in kcal.

APPENDIX 2E: ENERGY INTAKE OF CHILDREN AGED ~10-14 YEARS IN EUROPEAN COUNTRIES

Country	Age (years)	N	Energy (MJ/d)				Energy (kcal/d)			
			mean	*SD*	*P50*	*P5 – P95*	*mean*	*SD*	*P50*	*P5 – P95*
Boys										
Austria	10-14	248	7.0	2.0						
Belgium	13-15	74	10.6	2.1						
Bulgaria	10-14	167	11.1[1]	4.5[1]	10.2[1]		2,659	1,071	2,450	
Denmark	10-13	164	9.3	2.5	9.3	5.9-12.7				
France	10-14	160	8.7	0.2						
Germany	10-11	199	8.0	1.8	7.6	5.4-11.3	1,908	436	1,813	1,297-2,682
	12	114	10.6	3.2	10.4	6.1-18.1	2,522	769	2,470	1,455-4,316
	13-14	214	11.7	3.8	11.4	6.3-18.4	2,803	917	2,726	1,503-4,383
Hungary	11-14	124	10.4	1.9			2,489	453		
Ireland	9-12	148	8.0	1.6	7.9	5.8-10.5	1,890	369	1,871	1,383-2,495
	13-14	95	9.0	2.1	8.9	5.8-12.9	2,137	502	2,103	1,398-3,073
Italy	10-<18	108	10.8	3.1	10.6	6.8-15.5	2,576	744	2,540	1,630-3,709
The Netherlands	9-13	351			9.8	6.6-13.7			2,330	1,576-3,253
Norway	13	590	9.5	3.5						
Poland	10-12	128	10.3	3.4	10.1		2,468	821	2,414	
	13-15	218	13.2	4.6	12.7		3,145	1,092	3,027	
Spain	10-14	66	9.8	1.7						
Sweden	11-12	517	7.8	2.2	7.6	4.5-11.8	1,864	518	1,814	1,075-2,811
United Kingdom	11-18	238	8.5	2.1	8.1	4.5-12.7[2]	2,007	508	1,916	1,074-3,019[2]
Girls										
Austria	10-14	239	6.1	1.7						
Belgium	13-15	89	8.0	2.0						
Bulgaria	10-14	180	9.3[1]	3.7[1]	9.0[1]		2,225	881	2,143	
Denmark	10-13	196	7.9	2.3	7.8	4.5-11.3				
France	10-14	144	7.5	0.1						
Germany	10-11	198	7.6	1.6	7.7	5.2-10.3	1,808	394	1,842	1,234-2,444
	12	103	9.3	3.2	8.3	4.2-14.7	2,222	763	1,986	1,007-3,508
	13-14	230	9.5	2.7	9.3	5.6-14.1	2,277	651	2,224	1,332-3,352
Hungary	11-14	111	9.2	1.5			2,195	358		
Ireland	9-12	150	7.0	1.4	6.9	4.6-9.4	1,654	333	1,649	1,089-2,227
	13-14	93	7.0	1.6	7.0	4.3-9.9	1,674	377	1,667	1,009-2,356
Italy	10-<18	139	8.7	2.2	8.7	5.0-12.5	2,091	532	2,081	1,187-2,999
The Netherlands	9-13	352			8.4	5.9-11.3			2,010	1,408-2,705
Norway	13	515	8.1	2.6						
Poland	10-12	121	8.9	2.7	8.8		2,124	646	2,098	
	13-15	134	10.0	3.7	9.7		2,385	882	2,308	
Spain	10-14	53	8.4	0.9						
Sweden	11-12	499	6.9	1.9	6.7	4.0-10.1	1,650	453	1,613	958-2,410
United Kingdom	11-18	215	6.9	1.7	6.9	3.6-10.3[2]	1,637	413	1,637	850-2,437[2]

[1]Calculated from values in kcal
[2]P2.5-97.5

APPENDIX 2F: ENERGY INTAKE OF ADOLESCENTS AGED ~15-18 YEARS IN EUROPEAN COUNTRIES

Country	Age (years)	N	Energy (MJ/d) mean	SD	P50	P5 – P95	Energy (kcal/d) mean	SD	P50	P5 – P95
Boys										
Austria	14-19	1,527	11.5	3.0						
Belgium	15-18	405	11.0	2.6	10.8		2,639	631	2,592	
Bulgaria	14-18	178	11.9[1]	4.1[1]	11.1[1]		2,842	974	2,657	
Denmark	14-17	101	10.1	3.2	10.5	5.0-14.9				
France	15-18	181	10.2	0.4						
Germany	15-17	294	14.3	5.4	13.4	8.0-23.0	3,414	1,286	3,202	1,905-5,498
Ireland	15-17	129	9.9	2.5	9.7	6.1-14.6	2,344	595	2,314	1,459-3,473
The Netherlands	14-18	352			11.0	7.7-15.0			2,622	1,830-3,580
Norway	16-19	92	13.9							
Poland	16-18	130	14.7	4.8	14.1		3,504	1,130	3,380	
Slovenia	14-16	1,085	12.8				3,053			
Spain	15-18	61	10.7	2.0						
Girls										
Austria	14-19	1,422	8.5	2.2						
Belgium	15-18	401	7.7	1.6	7.6		1,844	373	1,817	
Bulgaria	14-18	190	9.0[1]	3.4[1]	8.3[1]		2,149	824	1,994	
Denmark	14-17	134	7.4	2.3	7.1	4.3-11.2				
France	15-18	222	6.8	0.2						
Germany	15-17	317	9.9	3.8	9.3	5.4-16.2	2,364	916	2,228	1,284-3,853
Ireland	15-17	124	7.2	2.1	7.0	4.0-10.9	1,712	491	1,663	952-2,599
The Netherlands	14-18	354			8.4	5.9-11.3			2,008	1,406-2,703
Norway	16-19	86	9.1							
Poland	16-18	122	9.4	3.7	8.8		2,237	887	2,108	
Slovenia	14-16	1,346	9.8				2,332			
Spain	15-18	57	7.9	1.1						

[1]Calculated from values in kcal

APPENDIX 3A: POPULATION, METHODS AND PERIOD OF DIETARY ASSESSMENT IN ADULTS IN EUROPEAN COUNTRIES

Country	Population	Dietary assessment method	Year of survey	Reference
Austria	Men and women aged 19-64 years	24-hour recall	2005-2006	(Elmadfa et al., 2009a; Elmadfa et al., 2009b)
	Men and women aged 65 years and over	3-day record	2007-2008	(Elmadfa et al., 2009a; Elmadfa et al., 2009b)
Belgium	Men and women aged 19-59 years	2x 24-hour recall	2004-2005	(De Vriese et al., 2006)
	Men and women aged 60-74 years	2x 24-hour recall	2004-2005	(De Vriese et al., 2006)
	Men and women aged 75 years and over	2x 24-hour recall	2004-2005	(De Vriese et al., 2006)
Bulgaria	Men and women aged 18-30 years	24-hour recall	1998	(Abrasheva et al., 1998)
	Men and women aged 30-60 years	24-hour recall	1998	(Abrasheva et al., 1998)
	Men and women aged 60-75 years	24-hour recall	1998	(Abrasheva et al., 1998)
	Men and women aged >75 years	24-hour recall	1998	(Abrasheva et al., 1998)
Czech Republic	Men and women aged 19-64 years	24-hour recall	2000-2001	(Cifková and Škodová, 2004; Elmadfa et al., 2009b)
Denmark	Men and women aged 18-75 years	7-day record	2003-2008	(Pedersen et al., 2010)
	Men and women aged 18-24 years	7-day record	2003-2008	(Pedersen et al., 2010)
	Men and women aged 25-34 years	7-day record	2003-2008	(Pedersen et al., 2010)
	Men and women aged 35-44 years	7-day record	2003-2008	(Pedersen et al., 2010)
	Men and women aged 45-54 years	7-day record	2003-2008	(Pedersen et al., 2010)
	Men and women aged 55-64 years	7-day record	2003-2008	(Pedersen et al., 2010)
	Men and women aged 65-75 years	7-day record	2003-2008	(Pedersen et al., 2010)
Estonia	Men and women aged 19-64 years	24-hour recall	1997	(Elmadfa et al., 2009b; Pomerleau et al., 2001)
	Men and women aged 19-34 years	24-hour recall	1997	(Elmadfa et al., 2009b; Pomerleau et al., 2001)
	Men and women aged 35-49 years	24-hour recall	1997	(Elmadfa et al., 2009b; Pomerleau et al., 2001)
	Men and women aged 50-64 years	24-hour recall	1997	(Elmadfa et al., 2009b; Pomerleau et al., 2001)
Finland	Men and women aged 25-64 years	48-hour recall	2007	(Paturi et al., 2008; Pietinen et al., 2010)
	Men and women aged 25-34 years	48-hour recall	2007	(Paturi et al., 2008)
	Men and women aged 35-44 years	48-hour recall	2007	(Paturi et al., 2008)
	Men and women aged 45-54 years	48-hour recall	2007	(Paturi et al., 2008)
	Men and women aged 55-64 years	48-hour recall	2007	(Paturi et al., 2008)
	Men and women aged 65-75 years	48-hour recall	2007	(Paturi et al., 2008)
France	Men and women aged 19-64 years	3x 24-hour recall	2006-2007	(Elmadfa et al., 2009b)
	Men and women aged 65-74 years	3x 24-hour recall	2006-2007	(Elmadfa et al., 2009b)
Germany	Men and women aged 19-80 years	24-hour recall + Dietary History	2005-2006	(MRI, 2008b)
	Men and women aged 19-24 years	24-hour recall + Dietary History	2005-2006	(MRI, 2008b)
	Men and women aged 25-34 years	24-hour recall + Dietary History	2005-2006	(MRI, 2008b)
	Men and women aged 35-50 years	24-hour recall + Dietary History	2005-2006	(MRI, 2008b)
	Men and women aged 51-64 years	24-hour recall + Dietary History	2005-2006	(MRI, 2008b)
	Men and women aged 65-80 years	24-hour recall + Dietary History	2005-2006	(MRI, 2008b)

Country	Population	Dietary assessment method	Year of survey	Reference
Greece	Men and women aged 19-64 years	Food Frequency Questionnaire + 24-hour recall in subgroup	1994-1999	(Elmadfa et al., 2009b)
	Men and women aged 65 years and over	Food Frequency Questionnaire	1994-1999	(Elmadfa et al., 2009b)
Hungary	Men and women aged 18-59 years	3-day record	2003-2004	(Elmadfa et al., 2009b; Rodler et al., 2005)
	Men and women aged 18-34 years	3-day record	2003-2004	(Elmadfa et al., 2009b; Rodler et al., 2005)
	Men and women aged 35-59 years	3-day record	2003-2004	(Elmadfa et al., 2009b; Rodler et al., 2005)
	Men and women aged 60 years and over	3-day record	2003-2004	(Elmadfa et al., 2009b; Rodler et al., 2005)
Ireland	Men and women aged 18-64 years	4-day record	2008-2010	(IUNA, 2011)
	Men and women aged 18-35 years	4-day record	2008-2010	(IUNA, 2011)
	Men and women aged 36-50 years	4-day record	2008-2010	(IUNA, 2011)
	Men and women aged 51-64 years	4-day record	2008-2010	(IUNA, 2011)
	Men and women aged aged 65-90 years	4-day record	2008-2010	(IUNA, 2011)
Italy	Men and women aged 18-<65years	Consecutive 3-day food record	2005-2006	(Sette et al., 2010)
	Men and women aged 65 and over	Consecutive 3-day food record	2005-2006	(Sette et al., 2010)
Latvia	Men and women aged 17-26 years	2 non-consecutive 24-hour dietary recalls + FFQ	2008	(Joffe et al., 2009)
	Men and women aged 27-36 years	2 non-consecutive 24-hour dietary recalls + FFQ	2008	(Joffe et al., 2009)
	Men and women aged 37-46 years	2 non-consecutive 24-hour dietary recalls + FFQ	2008	(Joffe et al., 2009)
	Men and women aged 47-56 years	2 non-consecutive 24-hour dietary recalls + FFQ	2008	(Joffe et al., 2009)
	Men and women aged 57-64 years	2 non-consecutive 24-hour dietary recalls + FFQ	2008	(Joffe et al., 2009)
Lithuania	Men and women aged 19-64 years	24-hour recall	2007	(Elmadfa et al., 2009b)
The Netherlands	Men and women aged 19-30 years	2 non-consecutive 24-hour dietary recalls	2007-2010	(van Rossum et al., 2011)
	Men and women aged 31-50 years	2 non-consecutive 24-hour dietary recalls	2007-2010	(van Rossum et al., 2011)
	Men and women aged 51-69 years	2 non-consecutive 24-hour dietary recalls	2007-2010	(van Rossum et al., 2011)
Norway	Men and women aged 19-64 years	Food Frequency Questionnaire	1997	(Elmadfa et al., 2009b)
	Men and women aged 20-29 years	Food Frequency Questionnaire	1997	(Johansson and Sovoll, 1999)
	Men and women aged 30-39 years	Food Frequency Questionnaire	1997	(Johansson and Sovoll, 1999)
	Men and women aged 40-49 years	Food Frequency Questionnaire	1997	(Johansson and Sovoll, 1999)
	Men and women aged 50-59 years	Food Frequency Questionnaire	1997	(Johansson and Sovoll, 1999)
	Men and women aged 65 years and over	Food Frequency Questionnaire	1997	(Elmadfa et al., 2009b)
	Men and women aged 60-69 years	Food Frequency Questionnaire	1997	(Johansson and Sovoll, 1999)
	Men and women aged 70-79 years	Food Frequency Questionnaire	1997	(Johansson and Sovoll, 1999)
Poland	Men and women aged 19-25 years	24-hour recall	2000	(Szponar et al., 2003)
	Men and women aged 26-60 years	24-hour recall	2000	(Szponar et al., 2003)
	Men and women aged 61 years and over	24-hour recall	2000	(Szponar et al., 2003)

Country	Population	Dietary assessment method	Year of survey	Reference
Portugal	Men and women aged 18-≥65 years	Food Frequency Questionnaire	1999-2003	(Elmadfa et al., 2009b; Lopes et al., 2006). *Data collected in Porto.*
	Men and women aged 18-39 years	Food Frequency Questionnaire	1999-2003	(Lopes et al., 2006). *Data collected in Porto.*
	Men and women aged 40-49 years	Food Frequency Questionnaire	1999-2003	(Lopes et al., 2006). *Data collected in Porto.*
	Men and women aged 50-64 years	Food Frequency Questionnaire	1999-2003	(Lopes et al., 2006). *Data collected in Porto.*
	Men and women aged 65 years and over	Food Frequency Questionnaire	1999-2003	(Elmadfa et al., 2009b; Lopes et al., 2006). *Data collected in Porto.*
Romania	Men and women aged 19-64 years	Personal interview	2006	(Elmadfa et al., 2009b)
	Men and women aged 65 years and over	Personal interview	2006	(Elmadfa et al., 2009b)
Slovenia	Men and women aged 18-65 years	Food frequency questionnaire and 24 hour recall	2007-2008	(Gabrijelčič Blenkuš et al., 2009)
Spain	Men and women aged 18-24 years	2 non-consecutive 24-hour recalls	2002-2003	(Serra-Majem et al., 2007). *Data collected in Catalonia.*
	Men and women aged 25-44 years	2 non-consecutive 24-hour recalls	2002-2003	(Serra-Majem et al., 2007). *Data collected in Catalonia.*
	Men and women aged 45-64 years	2 non-consecutive 24-hour recalls	2002-2003	(Serra-Majem et al., 2007). *Data collected in Catalonia.*
	Men and women aged 65-75 years	2 non-consecutive 24-hour recalls	2002-2003	(Serra-Majem et al., 2007) *Data collected in Catalonia.*
Sweden	Men and women aged 17-74 years	7-day record	1997-1998	(Becker and Pearson, 2002)
	Men and women aged 17-24 years	7-day record	1997-1998	(Becker and Pearson, 2002)
	Men and women aged 25-34 years	7-day record	1997-1998	(Becker and Pearson, 2002)
	Men and women aged 35-44 years	7-day record	1997-1998	(Becker and Pearson, 2002)
	Men and women aged 45-54 years	7-day record	1997-1998	(Becker and Pearson, 2002)
	Men and women aged 55-64 years	7-day record	1997-1998	(Becker and Pearson, 2002)
	Men and women aged 65-74 years	7-day record	1997-1998	(Becker and Pearson, 2002)
United Kingdom	Men and women aged 19-64 years	4-day food diary	2008-2010	(Bates et al., 2011)
	Men and women aged 65 years and over	4-day food diary	2008-2010	(Bates et al., 2011)

APPENDIX 3B: ENERGY INTAKE OF ADULTS AGED ~19-65 YEARS IN EUROPEAN COUNTRIES

Country	Age (years)	N	Energy (MJ/d)				Energy (kcal/d)			
			mean	*SD*	*P50*	*P5 – P95*	*mean*	*SD*	*P50*	*P5 – P95*
Men										
Austria	19-64	778	9.0	3.1						
Belgium	19-59	413	10.8	3.0	10.4		2,578	720	2,495	
Czech Republic	19-64	1,046	12.4	3.7						
Denmark	18-75	1,569	10.4	2.9	10.3	7.0-14.3[1]				
Estonia	19-64	900	9.6	4.8			2,278	1,144		
Finland	25-64	730	9.2	3.0			2,206	705		
France	19-64	852	10.0	0.1						
Germany	19-64	4,912	11.0	4.3						
Greece	19-64	8,365	10.4	3.0						
Hungary	18->60	473	11.7	2.4			2,792	570		
Ireland	18-64	634	10.1	2.7	10.0		2,397	650	2,377	
Italy	18-<65	1,068	10.0	2.7	9.8	6.2-14.6	2,390	650	2,332	1,471-3,499
Lithuania	19-65	849	10.3	4.3						
Norway	19-64	1,050	11.1	3.9						
Portugal	18-≥65	917	9.9	2.3			2,367	560	2,300	1,551-3,369
Romania	19-64	177	13.9	5.2						
Slovenia	18-65	n.a.	13.1[2] 9.0[3]							
Sweden	17-74	589	9.9	2.7	9.6	6.0-14.8				
United Kingdom	19-64	346	9.2	3.0	8.9	4.7-17.1[4]	2,200	706	2,112	1,115-4,058[4]
Women										
Austria	19-64	1,345	7.5	2.5						
Belgium	19-59	460	7.0	1.9	6.8		1,680	447	1,637	
Czech Republic	19-64	1,094	9.7	3.0						
Denmark	18-75	1,785	7.9	2.1	7.9	5.4-10.5[1]				
Estonia	19-64	1,115	6.9	3.2			1,640	766		
Finland	25-64	846	6.8	2.0			1,620	483		
France	19-64	1,499	7.2	0.1						
Germany	19-64	6016	8.1	2.5						
Greece	19-64	12,034	8.3	2.4						
Hungary	18->60	706	9.2	1.8			2,205	429		
Ireland	18-64	640	7.2	2.0	7.2		1,725	482	1,706	
Italy	18-<65	1,245	8.1	2.2	8.0	4.9-11.8	1,939	526	1,909	1,162-2,827
Lithuania	18-65	1,087	7.4	3.0						
Norway	19-64	1,146	8.1	2.7						
Portugal	18-≥65	1,472	8.7	2.1			2,079	494	2,040	1,352–2,953
Romania	19-64	341	11.4	4.9						
Slovenia	18-65	n.a.	11.3[2] 7.5[3]							
Sweden	17-74	626	7.8	2.3	8.3	3.7-11.2				
United Kingdom	19-64	461	6.9	2.0	6.7	3.1-11.4[4]	1,638	477	1,604	747-2,700[4]

[1]P10-P90
[2]Food frequency questionnaire
[3]24-h recall
[4]P2.5-P97.5
n.a.: not available

APPENDIX 3C: ENERGY INTAKE OF ADULTS AGED ~19-34 YEARS IN EUROPEAN COUNTRIES

Country	Age (years)	N	Energy (MJ/d)				Energy (kcal/d)			
			mean	*SD*	*P50*	*P5 – P95*	*mean*	*SD*	*P50*	*P5 – P95*
Men										
Bulgaria	18-30	208	11.8[1]	5.1[1]	10.8[1]		2,820	1,231	2,590	
Denmark	18-24	105	11.1	3.1	10.8	6.4-15.8				
	25-34	234	11.3	2.9	11.0	7.0-16.1				
Estonia	19-34	396	10.3[1]	5.3[1]			2,464	1,255		
Finland	25-34	137	9.9	3.2			2,362	764		
Germany	19-24	510	12.0[1,]	0.20[1,2]	11.2[1]	6.1-21.0[1]	2,872	48.12[2]	2,680	1,452-5,023
	25-34	690	11.6[1]	0.17[1,2]	10.8[1]	6.3-19.6[1]	2,783	41.36[2]	2,581	1,505-4,692
Hungary	18-34	136	12.4	2.3			2,965	551		
Ireland	18-35	276	10.7	2.9	10.6		2,553	664	2,540	
Latvia	17-26	191	10.0[1]				2,394			
	27-36	116	10.0[1]				2,393			
The Netherlands	19-30	356			11.5	8.1-15.6			2,573	1,940-3,731
Norway	20-29	248	12.6							
	30-39	269	11.4							
Poland	19-25	191	15.3	4.6	15.1		3,657	1,090	3,613	
Portugal	18-39	179					2,496	584	2,427	1,622-3,577
Spain	18-24	127	10.0[1]				2,384			
	25-44	326	9.4[1]				2.242			
Sweden	17-24	67	10.4	3.2	10.2	4.9-16.1				
	25-34	128	10.2	2.4	9.9	6.3-14.4				
Women										
Bulgaria	18-30	204	8.2[1]	3.2[1]	7.5[1]		1,954	758	1,789	
Denmark	18-24	150	8.2	2.3	8.1	4.9-12.2				
	25-34	340	8.3	2.2	8.3	4.9-11.8				
Estonia	19-34	459	7.4[1]	3.4[1]			1,760	801		
Finland	25-34	180	7.2	2.2			1,711	525		
Germany	19-24	510	8.4[1]	0.13[1,2]	8.0[1]	4.8-13.3[1]	1,996	30.69[2]	1,914	1,141-3,171
	25-34	972	8.5[1]	0.09[1,2]	8.0[1]	4.9-13.2[1]	2,031	21.11[2]	1,929	1,165-3,151
Hungary	18-34	176	9.5	1.7			2,280	407		
Ireland	18-35	255	7.5	2.3	7.4		1,783	542	1,762	
Latvia	17-26	187	7.1[1]				1,690			
	27-36	90	6.4[1]				1,523			
The Netherlands	19-30	347[4]			8.4	5.9-11.3			1,999	1,399-2,693
Norway	20-29	268	8.7							
	30-39	289	8.2							
Poland	19-25	211	8.2	3.2	7.8		1,957	763	1,872	
Portugal	18-39	299					2,141	515	2,096	1,409-3,109
Spain	18-24	182	7.8[1]				1,869			
	25-44	376	7.2[1]				1,714			
Sweden	17-24	70	8.0	1.7	7.9	5.4-11.2				
	25-34	132	7.8	1.8	7.5	5.3-10.6				

[1]Calculated from values in kcal
[2]se

APPENDIX 3D: ENERGY INTAKE OF ADULTS AGED ~35-64 YEARS IN EUROPEAN COUNTRIES

Country	Age (years)	N	Energy (MJ/d)				Energy (kcal/d)			
			mean	*SD*	*P50*	*P5 – P95*	*mean*	*SD*	*P50*	*P5 – P95*
Men										
Bulgaria	30-60	224	11.7[1]	3.8[1]	11.5[1]		2,788	904	2,747	
Denmark	35-44	318	11.1	3.1	10.9	6.2-16.6				
	45-54	336	10.3	2.7	10.3	6.4-14.8				
	55-64	336	9.9	2.7	9.6	5.7-14.8				
Estonia	35-49	319	9.2[1]	4.6[1]			2,190	1,103		
	50-64	185	8.5[1]	3.7[1]			2,033	873		
Finland	35-44	177	9.5	3.2			2,277	806		
	45-54	190	9.2	3.4			2,202	603		
	55-64	226	8.6	2.5			2,061	636		
Germany	35-50	2,079	11.0[1]	0.08[1,2]	10.5[1]	6.0[1]-17.9[1]	2,640	19.29[2]	2,509	1,435-4,271
	51-64	1,633	10.0[1]	0.08[1,2]	9.6[1]	5.4[1]-16.1[1]	2,400	19.60[2]	2,297	1,301-3,843
Hungary	35-59	199	12.0	2.2			2,862	533		
Ireland	36-50	205	9.7	2.5	9.6		2,322	591	2,310	
	51-64	153	9.3	2.4	9.1		2,217	581	2,157	
Latvia	37-46	136	9.7[1]				2,319			
	47-56	155	9.3[1]				2,230			
	57-64	108	8.9[1]				2,121			
The Netherlands	31-50	348			11.1	7.7-15.1			2,647	1,848-3,611
	51-69	351			10.0	6.9-13.9			2,390	1,637-3,309
Norway	40-49	256	10.5							
	50-59	196	9.8							
Poland	26-60	865	13.0	4.4	12.6		3,114	1,056	3,019	
Portugal	40-49	197	10.3[1]				2,453	530	2,406	1,679-3,372
	50-64	295	9.9[1]				2,354	561	2,300	1,591-3,271
Spain	45-64	265	8.4[1]				2,018			
Sweden	35-44	143	10.0	2.7	9.7	6.0-15.0				
	45-54	18	9.8	2.8	9.5	5.6-15.0				
	55-64	68	9.2	2.2	9.0	5.6-12.6				
Women										
Bulgaria	30-60	224	8.2[1]	3.0[1]	7.9[1]		1,956	724	1,891	
Denmark	35-44	412	8.3	2.2	8.2	4.9-12.1				
	45-54	359	7.6	1.9	7.8	4.6-10.5				
	55-64	326	7.5	1.9	7.3	4.9-10.6				
Estonia	35-49	376	6.7[1]	3.2[1]			1,605	765		
	50-64	280	6.2[1]	2.8[1]			1,491	676		
Finland	35-44	211	7,1	2.1			1,687	497		
	45-54	232	6.7	1.9			1,601	461		
	55-64	223	6.3	1.8			1,502	433		
Germany	35-50	2,694	8.2[1]	0.05[1,2]	7.8[1]	4.6[1]-12.8[1]	1,948	11.74[2]	1,870	1,098-3,066
	51-64	1,840	7.8[1]	0.05[1,2]	7.5[1]	4.6[1]-11.9[1]	1,856	13.10[2]	1,793	1,092-2,837
Hungary	35-59	295	9.4	1.9			2,237	443		
Ireland	36-50	232	7.1	1.9	7.1		1,696	444	1,684	
	51-64	153	7.0	1.7	7.1		1,674	416	1,682	
Latvia	37-46	136	6.5[1]				1,562			
	47-56	149	6.7[1]				1,608			
	57-64	109	6.4[1]				1,530			
The Netherlands	31-50	351			8.2	5.7-11.1			1,956	1,361-2,644
	51-69	353			7.8	5.3-10.6			1,849	1,268-2,525
Norway	40-49	289	7.7							
	50-59	196	7.5							
Poland	26-60	1,997	8.4	3.0	8.1		1,997	721	1,927	

Country	Age (years)	N	Energy (MJ/d)				Energy (kcal/d)			
			mean	*SD*	*P50*	*P5 – P95*	*mean*	*SD*	*P50*	*P5 – P95*
Portugal	40-49	340	9.0[1]				2,160	478	2,127	1,488-2,959
	50-64	494	8.8[1]				2,102	498	2,065	1,382-3,012
Spain	45-64	337	6.6[1]				1,573			
Sweden	35-44	132	7.7	1.9	7.6	4.8-10.5				
	45-54	153	7.6	1.6	7.5	5.0-10.2				
	55-64	81	7.9	2.0	7.6	4.6-11.8				

[1]Calculated from values in kcal
[2]se

APPENDIX 3E: ENERGY INTAKE OF ADULTS AGED ~65 YEARS AND OVER IN EUROPEAN COUNTRIES

Country	Age (years)	N	Energy (MJ/d)				Energy (kcal/d)			
			mean	*SD*	*P50*	*P5 – P95*	*mean*	*SD*	*P50*	*P5 – P95*
Men										
Austria	65+	147	7.7	2.4						
Belgium	60-74	416	9.1	2.2	8.9		2,172	525	2,129	
	75+	389	8.3	2.2	8.0		1,993	527	1,923	
Bulgaria	60-75	186	10.2[1]	3.8[1]	9.7[1]		2,431	919	2,319	
	76+	101	9.0[1]	3.2[1]	8.6[1]		2,153	757	2,064	
Denmark	65-75	240	9.5	2.5	9.2	5.8-13.7				
Finland	65-74	229	7.7	2.3			1,848	554		
France	65-74	130	9.0	0.2						
Germany	65-80	1,469	9.2[1]	0.07[1,2]	8.9[1]	5.3-13.8[1]	2,191	16.32[2]	2,129	1,263-3,303
Greece	65+	2,508	8.5	2.5			2,018	600.6		
Hungary	60+	138	10.5	2.3			2,519	546		
Ireland	65+	106	8.3	2.6	8.0		1,983	630	1,905	
Italy	65+	202	9.6	2.3	9.5	6.2-13.6	2,296	556	2,267	1,471-3,241
Norway	65+	176	9.0	3.1						
	70-79	131	8.7							
	60-70[4]	106	8.9							
Poland	61+	226	10.6	3.6	10.4		2,524	860	2,493	
Portugal	65+	246	9.3	2.2			2,219	530	2,161	1,455-3,206
Romania	65+	177	13.0	4.1						
Spain	65-75	122	7.1[1]				1,688			
Sweden	65-74	65	9.6	2.8	9.2	5.9-13.7				
United Kingdom	65+	96	8.3	2.1	8.3	3.7-11.8[3]	1,976	511	1,973	882-2,801[3]
Women										
Austria	65+	202	7.1	1.7						
Belgium	60-74	406	6.7	1.6	6.5		1,597	387	1,564	
	75+	355	6.2	1.5	6.1		1,482	351	1,462	
Bulgaria	60-75	194	8.1[1]	2.6[1]	7.7[1]		1,926	613	1,848	
	76+	113	7.6[1]	2.7[1]	7.6[1]		1,807	636	1,814	
Denmark	65-75	198	7.4	1.9	7.3	4.5-10.7				
Finland	65-74	234	5.9	1.7			1,412	414		
France	65-74	219	6.7	0.1						
Germany	65-80	1,562	7.3[1]	0.05[1,2]	7.1[1]	4.4-10.9[1]	1,753	12.47[2]	1,708	1,044-2,610
Greece	65+	3,600	6.8	2.1			1,620	491.7		
Hungary	60+	235	8.8	1.7			2,110	412		
Ireland	65+	120	6.5	1.6	6.3		1,555	382	1,508	
Italy	65+	316	7.7	2.0	7.6	4.6-11.4	1,834	486	1,828	1,094-2,732
Norway	65+	166	7.0	2.0						
	60-69	137	7.2							
	70-79	109	7.0							
Poland	61+	365	8.3	2.8	8.0		1,974	658	1,917	
Portugal	65+	339	8.0	1.9			1,910	444	1,878	1,226-2,736
Romania	65+	341	10.9	3.4						
Spain	65-75	122	5.7[1]				1,373			
Sweden	65-74	58	7.8	1.8	7.7	5.0-10.9				
United Kingdom	65+	128	6.4	1.3	6.2	4.1-8.9[3]	1,522	319	1,470	980-2,111[3]

[1]Calculated from values in kcal
[2]se
[3]P2.5-P97.5

APPENDIX 4: OVERVIEW OF THE APPROACHES USED BY SELECTED AUTHORITIES FOR THE ESTIMATION OF AVERAGE ENERGY REQUIREMENTS FOR ADULTS

	REE equations	Age ranges for calcula-tions	Body mass	PAL values	Source of PAL values	Method to estimate daily average energy requirements	Comments
SCF (1993)	Schofield's equations based on body mass, according to age and sex (FAO/WHO/UNU, 1985). Specific equations for adults ≥60 y based on some of the original data collected by Schofield et al., data on Scottish men and data on Italian men and women (Ferro-Luzzi, 1987; James et al., 1989): Men: 60-74 y: REE (MJ/d)=0.0499 x body mass +2.93; ≥75 y: REE (MJ/d)=0.035 x body mass + 3.43. Females: 60-74 y: REE (MJ/d)=0.0386 x body mass +2.88; ≥75 y: REE (MJ/d)=0.0410 x body mass + 2.61	18-29 y, 30-59 y, 60-74 y, ≥75 y	Observed European values taken from 11 studies (representative national samples and specific surveys), and weighted for the total number of adults in each age group in each country. Calculated body masses (from observed heights and a desirable BMI of 22).	Average PAL values varying between 1.33 and 2.10, including or without desirable physical activities, determined for each sex, according to age (18-59 y, 60-74 y, ≥75 y) and for observed body masses.	(FAO/WHO/UNU, 1985; Ferro-Luzzi, 1987; James and Schofield, 1990)	PAL x REE	EERs: i) for each sex, age group, 5 kg increase in body mass (between 60 and 80 kg for men and 45 to 70 kg for women) and for each 0.1 increase in PAL varying between 1.4 and 2.2. ii) for each sex, on average as well as for each age group, for either the desirable or the actual median body mass, and for average PALs with or without desirable physical activity.
AFSSA (2001)	Black's equations (Black et al., 1996): Men (MJ/d): 0.963 x body mass $^{0.48}$ x height $^{0.50}$ x age $^{-0.13}$ Women (MJ/d): 1.083 x body mass $^{0.48}$ x height $^{0.50}$ x age $^{-0.13}$	20-30 y, 31-40 y,41-50 y, 51-60 y, 61-70 y	Body mass (5 kg increase, from 55 to 100 kg for men, 45 to 90 kg for women) and height values for a BMI of 22 kg/m^2	1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2, 2.1, 2.2, 2.3	Several publications	PAL x REE	EAR for each sex, each age range, body mass and height for a BMI of 22 kg/m^2, and each 0.1 increase in PAL value. To be corrected for BMI value (to decrease EAR by 1 % for each 1 kg/m^2 exceeding the BMI of 22 kg/m^2, and to increase by 1 % for each 1 kg/m^2 lower than the BMI of 22 kg/m^2). 1.5 and 1.8 times REE for active and healthy elderly subjects (Black, 1996; Cynober et al., 2000; Roberts, 1996). No conclusions for elderly subjects aged ≥80 y

	REE equations	Age ranges for calcula-tions	Body mass	PAL values	Source of PAL values	Method to estimate daily average energy requirements	Comments
Health Coun-cil of the Nether-lands (2001)	Schofield's equations based on body mass, according to age and sex (FAO/WHO/UNU, 1985), modified for the older age groups (SCF, 1993).	19-30 y, 31-50 y, 51-70 y, ≥70 y	Calculated from observed Dutch height values (Hofman et al., 1995; Smit et al., 1994) and a BMI of 22.5 (18-50 y), 24 (51-70 y) and 25 (≥71 y) (Troiano et al., 1996; WHO, 1995b)	At the low average PAL in NL: 1.7 (19-50 y), 1.6 (51-70 y), and 1.5 (≥71 y). At the adequate PAL: 1.9 (19-50 y), 1.8 (51-70 y), and 1.7 (≥71 y).	DLW data (Black et al., 1996)	PAL x REE	EAR for each sex, age group, and for PAL values accounting either for the low average level of physical activity in the Netherlands or for an adequate level of physical activity.
FAO/ WHO/ UNU (2004)	Schofield's equations (1985)	18-30 y, 30-60 y, >60 y	Every 5 kg increase in body mass (between 50 and 90 kg for men, between 45 and 85 kg for women)	3 PAL ranges associated with a population's lifestyle: 1.40-1.69 (sedentary or light activity), 1.70-1.99 (active or moderately active), and 2.00-2.40 (vigorous or vigorously active) For calculations: 1.45, 1.60, 1.75, 1.90, 2.05 and 2.20	-	PAL x REE	Several sets of values, i.e. for men and women, for three age ranges, six PAL values, and for every 5 kg increase in body mass, and expressed as MJ/d or kcal/d, as well as per kg of body mass
NNR (2004)	Schofield's equations based on body mass, according to age and sex (FAO/WHO/UNU, 1985), modified for the older age groups (SCF, 1993).	18-30 y, 31-60 y, 61-74 y, ≥75 y	Mean corrected reference body masses for each sex and age range between 18 and 74 y, calculated based on mean population body masses in Denmark (1995), Sweden (1997-98) and Finland (Finrisk, 2000) (adjusted for individuals with a BMI ≠ 18.5-25.0). For the age range ≥75 y, EER was calculated using reference body masses for each sex by subtracting 1 kg from the body masses used for the age group 61-74 y	EAR estimates proposed for three PAL values: 1.4 (sedentary), 1.6 (normal), 1.8 (active)	Studies using DLW measurements (Ainsworth et al., 2000; Black et al., 1996)	PAL x REE	EER assuming normal body mass and energy balance, for each sex, each age range, and three PAL values

	REE equations	Age ranges for calcula-tions	Body mass	PAL values	Source of PAL values	Method to estimate daily average energy requirements	Comments
IoM (2005)	/	≥19 y	Tables of heights and body masses of men and women, corresponding to BMIs of 18.5, 22.5 and 25 kg/m^2. Reference body masses for a BMI of 22.5 kg/m^2 for men and a BMI of 21.5 kg/m^2 for women corresponding to the 50th percentile among 19-y-old subjects (Kuczmarski et al., 2000) Calculations done for body masses for a BMI of 18.5 and for a BMI of 24.99, for each 0.05 m increase in height (varying between 1.45 and 1.95 m).	1.0-1.39 (sedentary), 1.4-1.59 (low active), 1.6-1.89 (active), 1.9-2.49 (very active). PA coefficient for the equations = 1.00 (for sedentary men and women), 1.11 (for low active men), 1.12 (for low active women), 1.25 (for active men), 1.27 (for active women), 1.48 (for very active men), 1.45 (for very active women).	A dataset of adults with normal body mass using DLW measurements (IoM, 2005)	Men: EER [kcal/d] = 662 – (9.53 x age [y]) + PA x (15.91 x body mass [kg] + 539.6 x height [m]) (n=169, SE fit=284.5 kcal, R^2=0.75) Women: EER [kcal/d]=354 – (6.91 x age [y]) + PA x (9.36 x body mass [kg] + 726 x height [m]) (n=238, SE fit=231.6, R^2=0.74)	EERs for 30-year-old men and women of various heights (between 1.45 and 1.95 m), with BMIs of 18.5 and 24.99 kg/m^2 and the corresponding body masses. For each year below 30: to add 7 kcal/d for women and 10 kcal/d for men. For each year above 30: to subtract 7 kcal/d for women and 10 kcal/d for men.
SACN (2011)	Henry's equations (Henry, 2005) based on body mass and height, according to age and sex.	19-24 y, 25-34 y, 35-44 y, 45-54 y, 65-74 y, ≥75 y, all adults	Calculated from British height values (Health Survey for England , data for 2009) and a BMI of 22.5	Median PAL of 1.63 for both sexes and all ages. For older adults with reduced mobility or not in good health, the PAL value of 1.49 (=25th centile) may be used. PAL values of 1.49 for “less active” and of 1.78 for “more active” correspond to 25th and 75th centile of PAL distribution. Examples are also given of the changes in PAL associated with increased activity.	Median, 25th and 75th percentiles from DLW studies (Moshfegh et al., 2008; Subar et al., 2003; Tooze et al., 2007) in US populations with similar levels of overweight and obesity and similar ethnic composition as the UK population. Exclusion of subjects with PAL <1.27 (n=38) and >2.5 (n=1).	PAL x REE	Energy requirements for men and women for seven age categories and all men / all women: population EAR (median value), and energy requirements for less active and more active people. Values for each sex and each age group, at observed mean height-for-age values and body masses corresponding to a BMI of 22.5 kg/m^2. Energy reference values for older adults with maintained general health and mobility: unlikely to differ from younger adults. For the extreme elderly, likely PAL of 1.49 (25th centile) or lower (e.g. 1.38 observed in some otherwise healthy elderly subjects (Rothenberg et al., 2000)).

	REE equations	Age ranges for calcula-tions	Body mass	PAL values	Source of PAL values	Method to estimate daily average energy requirements	Comments
D-A-CH (2012)	Based on Schofield's equations (FAO/WHO/UNU, 1985), according to each sex	19-<25 y 25-<51 y 51-<65 y ≥65 y	Calculated from German height values and a BMI of 22 (women), 24 (men)	PAL values provided for different work or free time activities: 1.2 (exclusively sedentary or bed-bound), 1.4-1.5 (exclusively seated work with little or no physical activity during leisure time), 1.6-1.7 (seated work, but occasionally also including work standing and moving around), 1.8-1.9 (Work including both standing and moving around), 2.0-2.4 (very strenuous work). PAL values used for calculations: - desired physical activity: 1.75 (15-24 y), 1.70 (25-50 y), 1.60 (51 y and older); low physical activity (1.45), high physical activity (2.2) - 1.4, 1.6, 1.8, 2.0	(Black et al., 1996; SCF, 1993; Shetty et al., 1996)	PAL x REE	Average energy requirements for both sexes and for four age groups

APPENDIX 5: OVERVIEW OF THE APPROACHES TO ESTIMATE AVERAGE ENERGY REQUIREMENTS FOR INFANTS AND YOUNG CHILDREN OF SELECTED COUNTRIES AND AUTHORITIES OTHER THAN FAO/WHO/UNU AND IOM

	Age range	EAR calculation	Body mass used for EAR calculations	Comments
SCF (1993)	0-36 months	Adapted from British EARs for infants and young children (DoH, 1991)	Rounded British average body masses (except for age 1 month: US data (Hamill et al., 1977))	EAR only intended for formula-fed infants, at 1, 3, 6, 9, 12, 18, 24, 30 and 36 months and for each sex
Health Council of the Netherlands (2001)	Infants	24 h energy consumption (based on DLW data (Butte et al., 2000a; de Bruin et al., 1998)) + deposited energy for growth (calculated considering Dutch body masses, body's protein and fat percentages at the age-group boundaries)	Dutch reference body masses (Fredriks et al., 1998; Fredriks et al., 2000a; Fredriks et al., 2000b; TNO/LUMC, 1998)	EAR, in MJ/d per kg of body mass and in MJ per d, without distinction on sex, for 0-2, 3-5, 6-11 months
AFSSA (2001)	Infants	Energy expenditure per kg body mass x body mass values (according to sex) + deposited energy for growth (values differing for boys and girls and based on mean daily rates of protein and lipid deposition) (Butte, 1996)	Origin of body mass values not specified	EAR only intended for formula-fed infants, for each sex and for each one month increase in age. Values for the first two months corrected for the digestibility of feeding formulae
NNR (2004)	0-23 months	Energy expenditure (DLW data on healthy children, (Butte et al., 1996; Butte et al., 2000a; Tennefors et al., 2003)) + deposited energy for growth	Values based on the mean reference values from Denmark (Andersen et al., 1982), Norway (Knudtzon et al., 1988) and the Swedish (2000) and Finnish (1993) growth charts (values used only for the summary table for 0-17 y)	EARs valid for both breast-fed and formula-fed infants, per kg of body mass, at 1, 3, 6, 12, 18 months
SACN (2011)	Infants	FAO/WHO/UNU (2004) and Butte (2005) : TEE (equations as a function of body mass distinguishing breast-fed infants, formula-fed infants, and infants with mixed or unknown feeding (Butte, 2005)) + deposited energy for growth based on measured protein and fat gains (Butte et al., 2000b; Fomon et al., 1982) applied to UK body mass increments (UK-WHO Growth Standards)	UK-WHO Growth Standards (RCPCH, 2011)	EAR distinguishing breast-fed and formula-fed infants as well as infants with mixed or unknown feeding, for each sex and each one month increase in age
D-A-CH (2012)	Infants	Used the approach of Butte (1996)	Reference body masses based on median values for US infants	EARs for 0-<4 and 4-<12 months, for formula-fed infants

APPENDIX 6: OVERVIEW OF THE APPROACHES OF FAO/WHO/UNU (2004) AND IOM (2005) TO ESTIMATE DAILY AVERAGE ENERGY REQUIREMENTS FOR INFANTS, CHILDREN AND ADOLESCENTS

	FAO/WHO/UNU (2004)	**IoM (2005)**
Age	**Infants**	**0-36 months**
Method of calculation of TEE	Simple linear regression on body mass (kg). All infants (kcal/d):-99.4+88.6 body mass (n=320, r=0.85, s.e.e.=109 kcal/d). Breast-fed (kcal/d): -152.0 + 92.8 x body mass (n=195, r=0.87, s.e.e.=108 kcal/d) Formula-fed (kcal/d): -29.0+82.6 x body mass (n=125, r=0.85, s.e.e.=110 kcal/d).	Simple linear regression on body mass (kg). (kcal/d): – 100 + 89 x body mass
Source of data for the calculation	DLW data (Butte, 2001)	DLW data (IoM, 2005)
Body mass used for EAR calculations	Median body mass-for-age (WHO (1994) pooled breast-fed data set)	American reference body masses (Kuczmarski et al., 2000)
Calculation of energy deposition for growth	From gains in protein and fat and the corresponding energy deposition (Butte et al., 2000b), considering the median body mass gain according to age	From gains in protein and fat and the corresponding energy deposition (Butte et al., 2000b), considering the median body mass gain according to age (Guo et al., 1991)
EAR calculation	EARs = TEE + energy deposition during growth	EERs = TEE + energy deposition during growth
Comments	EARs with or without distinction of sex, with or without distinction of breast-fed and formula-fed infants, and for each month of age	EERs for each sex and for each month of age
Age	**1-18 y**	**3-18 y**
Method of calculation of TEE	Quadratic equations with body mass as the single predictor Boys (kcal/d): 310.2 + 63.3 x body mass - 0.263 body $mass^2$ (n=801, r=0.982, r^2=0.964, s.e.e.=124 kcal/d) Girls (kcal/d): 263.4 + 65.3 x body mass - 0.454 x body $mass^2$ (n=808, r=0.955, r^2=0.913, s.e.e.=155 kcal/d) For children between 1 and 2 years, TEE estimates were reduced by 7% as the predicted values would have been otherwise 7% higher than the actual measurements of TEE (Butte, 2001)	Nonlinear regression analysis, with age, height and body mass, considering sex and 4 categories of physical activity coefficients (for sedentary, low active, active, very active subjects) Boys (kcal/d) = 88.5 – (61.9 x age + PA x (26.7 x body mass + 903 x height)) (SE fit=82.6, R^2=0.98) Girls (kcal/d) = 135.3 – (30.8 x age + PA x (10.0 x body mass + 934 x height)) (SE fit=96.7, R^2=0.95).
Source of data for the calculation	Derived from data on DLW and HR monitoring (Torun, 2001)	Derived from data on DLW (IoM, 2005)
Body mass used for EAR calculations	Median body masses at the mid-point of each year (WHO reference values of body mass-for-age (1983))	US reference body masses and heights (Kuczmarski et al., 2000)
Calculation of energy deposition for growth	Mean daily body mass gain at each year of age (between 1-2 y and 17-18 y) (WHO, 1983) x average energy deposited in growing tissues (8.6 kJ/g of body mass gain, calculated considering estimated rates of protein and fat deposition) (Butte et al., 2000a; Butte, 2001)	Median daily rates of gain in body mass at each year of age (between 3.5 and 17.5 y) (Baumgartner et al., 1986) x energy deposited in growing tissues (calculated considering estimated rates of protein and fat deposition (Fomon et al., 1982; Haschke, 1989))
EAR calculation	EAR = TEE + energy deposition for growth	EER = TEE + energy deposition for growth
Comments	3 calculated sets of values: i) in absolute values, for each sex and for each one year increase, ii) per kg of body mass (EAR divided by the median body mass at each year), for each sex and for each one year increase, iii) for 1-5 y, considering only moderate physical activity, and for children 6-18 y considering moderate physical activity (after calculation of "average" PAL values, by dividing TEE by calculated REE (Schofield et al., 1985)), light and heavy physical activity.	Calculated for each sex, for each one year increase in age, and the 4 PAL categories (defined as for adults: sedentary, low active, active, very active)

APPENDIX 7: OVERVIEW OF THE APPROACHES TO ESTIMATE DAILY AVERAGE ENERGY REQUIREMENTS FOR CHILDREN AND ADOLESCENTS OF SELECTED COUNTRIES AND AUTHORITIES OTHER THAN FAO/WHO/UNU AND IOM

	Method of calculation of REE	Body mass used for EAR calculations	PAL values	Calculation of energy deposition for growth	EAR calculation	Comments
SCF (1993): 3-9 y, 10-18 y	**3-9 y:** NA (use of intake data) **10-18 y**: REE equations (Schofield et al., 1985)	Average body masses from 9 European countries, weighted on the basis of each country's population at a given age	**3-9 y:** NA **10-18 y:** values for moderate physical activity, for 10-13 y (1.65 for boys, 1.55 for girls) and 14-18 y (1.58 for boys, 1.50 for girls) based on (FAO/WHO/UNU, 1985)	**3-9 y:** NA **10-18 y:** calculated based on a total energy cost of growth of 21 kJ per g of daily body mass gain, values between 0.03 and 0.35 MJ/d, differing for boys and girls	**3-9 y:** average body mass for boys and girls x energy intake per kg of bm, without the 5% increment proposed by FAO/WHO/UNU (1985) **10-18 y:** approach of FAO/WHO/UNU (1985): REE x PAL + deposited energy for growth	**3.5-9.5 y:** EAR for each sex and one year increase in age between 3.5 and 9.5 y. **10.5-17.5 y:** EAR for each sex and one year increase between 10.5 and 17.5 y
Health Council of the Netherlands (2001): 1-18 y	REE equations ((Schofield et al., 1985) based on body mass)	Dutch reference body masses (Fredriks et al., 1998; Fredriks et al., 2000a; Fredriks et al., 2000b; TNO/LUMC, 1998)	DLW data (Torun et al., 1996) 1-3 y: 1.5; 4-8 y: 1.6; 9-13 y: 1.8; girls, 14-18 y: 1.7; boys, 14-18 y: 1.8	Accretion expenditure of growth calculated from Dutch bm, body's protein and fat percentages at the age group limits. Values between 0.05 and 0.13 MJ/d, differing for each sex.	EAR = REE x average PAL + deposited energy for growth	EAR for each sex and age range (1-3 y, 4-8 y, 9-13 y, 14-18 y) and PAL value.
AFSSA (2001): 1-9 y, 10-18 y	**1-9 y:** NA (use of energy expenditure from DLW data (Torun et al., 1996) **10-18 y**: REE equations based on height and body mass (FAO/WHO/UNU, 1985)	Average body mass for age (origin of body mass values not specified)	**1-9 y:** 3 PALs varying with age: average, low, high (French DLW data, 1999). Average value varying with age: 1.5 for 2-3 y, 1.55 for 4 y, 1.6 for 5 y, 1.75 for 6-9 y. **10-18 y:** 9 PAL values for each 0.1 increase in PAL between 1.4 and 2.2	Average energy stored in tissues, considering deposited protein and fat and body mass gain, generally differing for boys and girls	**1-9 y, for average PAL:** bm x energy expenditure per kg body mass (based on DLW data) + deposited energy for growth (corrected values for low and high PALs) **10-18 y:** REE x PAL + deposited energy for growth	**1-9 y:** EAR for each sex, each one year increase in age and each PAL. **10-18 y:** EAR for each sex, bm (between 30 and 80 kg for boys, 30-70 kg for girls), each PAL and the average BMI of each age. EARs corrected only for girls 10-18 y according to BMI above or below the average value.
NNR (2004): 2-5 y, 6-9 y, 10-17 y	**2-5 y:** NA (use of energy expenditure from DLW data (Torun et al., 1996)) **6-9 y:** use of published values (Torun et al., 1996) calculated from REE (FAO/WHO/UNU, 1985) and a moderate PAL value.	Values based on the mean reference values from Denmark (Andersen et al., 1982), Norway (Knudtzon et al., 1988) and the Swedish (2000) and Finnish (1993) growth charts	**2-5 y**: NA. **6-9 y**: moderate physical activity considering the evaluation of PAL values based on DLW, HR monitoring and activity-time allocation studies (Torun et al., 1996) **10-17 y:** 3 PAL categories (Torun et al., 1996). Light activity: for girls, 1.50 (10-13 y), 1.45 (14-17 y), for boys, 1.55 (10-13 y), 1.60 (14-17 y).	-	**2-5 y:** energy expenditure (DLW data on healthy children (Torun et al., 1996) + deposited energy for growth (2%) **6-9 y:** use of published values (Torun et al., 1996) **10-17 y:** REE x PAL	**2-9 y**: EAR per kg of bm, for each sex and each one year increase. **10-17 y:** EAR per kg of bm, for each sex, each one year increase, and each PAL category (light, moderate, heavy). **0-17 y:** EAR in MJ/d, for each sex, for 0-1, 3, 6, 12 months, then one year increase, considering average Nordic bm for age, moderate physical activity and the EAR per kg of body mass previously calculated

	Method of calculation of REE	Body mass used for EAR calculations	PAL values	Calculation of energy deposition for growth	EAR calculation	Comments
	10-17 y: REE equations ((Schofield et al., 1985) based on body mass)		Moderate activity: for girls, 1.70 (10-13 y), 1.65 (14-17 y), for boys, 1.75 (10-13 y), 1.80 (14-17 y). Heavy activity: for girls, 1.90 (10-13 y), 1.85 (14-17 y), for boys, 1.95 (10-13 y), 2.05 (14-17 y).			
SACN (2011): 1-18 y	Henry's equations (Henry, 2005) based on body mass and height	**1-4 y**: median body masses and heights indicated by the growth standards (RCPCH, 2011) **5-18 y:** median British body masses and heights (UK 1990 references) (Freeman et al., 1995)	Median, 25^{th} and 75^{th} percentiles of PAL values adjusted for growth (in terms of a 1 % increase, compilation of published DLW data) without distinction of sex: for age ranges 1-3 y (1.36, 1.40, 1.45), 4-9 y (1.43, 1.58, 1.70), 10-18 y (1.68, 1.75, 1.86).	Adjustments of PAL values for growth in terms of 1 % increase.	REE x PAL	Energy requirements for each sex and each one year increase in age: population EAR (calculated with median PAL value) and energy requirements for less active (25^{th} percentile of PALs), and more active (75^{th} percentile of PALs) subjects
D-A-CH (2012): 1-18 y	**1-<15 y:** NA (use of energy expenditure from DLW data (Torun et al., 1996)) **15-<19 y:** REE equations (FAO/WHO/UNU, 1985) based on body mass	**1-<15 y:** Reference body masses based on median values for US children **15-<19 y:** German data, calculating body masses from body heights and a BMI of 22 kg/m^2 for men and 21 kg/m^2 for women	**1-<15 y:** moderate physical activity considering the evaluation of PAL values based on DLW, HR monitoring and activity-time allocation studies (Torun et al., 1996) **15-<19 y:** moderate physical activity: 1.75; PALs of 1.4, 1.6, 1.8, 2.0 also used	**1-<15 y:** NA **15-<19 y:** NA	**1-<15 y:** Used the approach of Torun et al. (1996) **15-<19 y**: REE x PAL	EAR for each sex and age range: 1-<4 y, 4-<7 y, 7-<10 y, 10-<13 y, 13-<15 y, 15-<19 y

NA, not applicable

APPENDIX 8: REE CALCULATED WITH FIVE MOST USED PREDICTIVE EQUATIONS USING MEASURED HEIGHTS FROM SURVEYS IN 13 EU MEMBER STATES AND BODY MASSES TO YIELD A BMI OF 22

Age (years)	n	REE (MJ/d) estimated with **Mifflin et al 1990** Median (P5-P95)	REE (MJ/d) estimated with **Henry 2005** Median (P5-P95)	REE (MJ/d) estimated with **Müller et al 2004** Median (P5-P95)	REE (MJ/d) estimated with **Harris-Benedict (1919)** Median (P5-P95)	REE (MJ/d) estimated with **Schofield 1985** Median (P5-P95)	Lowest and highest median REE (MJ/d)	REE (kcal/d) estimated with **Mifflin et al 1990** Median (P5-P95)	REE (kcal/d) estimated with **Henry 2005** Median (P5-P95)	REE (kcal/d) estimated with **Müller et al 2004** Median (P5-P95)	REE (kcal/d) estimated with **Harris-Benedict (1919)** Median (P5-P95)	REE (kcal/d) estimated with **Schofield 1985** Median (P5-P95)	Lowest and highest median REE (kcal/d)
Men													
18 - 29	2771	7.1 (6.4-7.8)	7.0 (6.3-7.7)	7.2 (6.7-7.6)	7.4 (6.6-8.1)	7.3 (6.7-7.8)	7.0; 7.4	1700 (1533-1858)	1674 (1506-1836)	1711 (1607-1813)	1758 (1570-1943)	1737 (1602-1870)	1674; 1758
30 - 39	2971	6.8 (6.2-7.6)	6.7 (6.1-7.5)	7.0 (6.6-7.5)	7.0 (6.3-7.9)	7.0 (6.6-7.5)	6.7; 7.0	1635 (1486-1823)	1613 (1466-1796)	1666 (1574-1784)	1672 (1504-1879)	1668 (1577-1783)	1613; 1672
40 - 49	3780	6.6 (5.9-7.3)	6.6 (6.0-7.4)	6.8 (6.4-7.3)	6.6 (5.9-7.5)	6.9 (6.5-7.4)	6.6; 6.9	1571 (1421-1750)	1592 (1438-1781)	1621 (1528-1735)	1588 (1416-1789)	1654 (1560-1774)	1571; 1654
50 - 59	3575	6.3 (5.6-7.0)	6.6 (5.9-7.3)	6.6 (6.2-7.0)	6.2 (5.5-7.1)	6.9 (6.5-7.3)	6.2; 6.9	1496 (1334-1667)	1576 (1417-1737)	1571 (1472-1681)	1492 (1310-1686)	1645 (1547-1745)	1492; 1645
60 - 69	2611	6.0 (5.4-6.6)	6.0 (5.3-6.6)	6.4 (6.0-6.8)	5.9 (5.2-6.6)	6.1 (5.2-6.8)	5.9; 6.4	1437 (1279-1587)	1438 (1258-1589)	1531 (1437-1625)	1414 (1243-1582)	1454 (1241-1631)	1414; 1531
70 - 79	792	5.7 (5.1-6.4)	5.9 (5.2-6.6)	6.2 (5.8-6.7)	5.5 (4.8-6.4)	6.0 (5.2-6.8)	5.5; 6.2	1364 (1208-1540)	1416 (1252-1574)	1481 (1386-1593)	1320 (1144-1521)	1429 (1233-1614)	1320; 1481
80 - 89	55	5.4 (4.5-5.5)	5.8 (5.0-5.9)	6.0 (5.5-6.1)	5.2 (4.2-5.3)	5.8 (4.9-6.0)	5.2; 6.0	1295 (1085-1323)	1375 (1192-1416)	1437 (1307-1543)	1236 (995-1266)	1379 (1161-1429)	1236; 1437
90+	12	5.2 (4.2-5.7)	5.8 (4.8-6.3)	5.8 (5.2-6.1)	4.9 (3.7-5.4)	5.8 (4.6-6.5)	4.9; 5.8	1243 (995-1354)	1389 (1146-1515)	1398 (1252-1466)	1160 (890-1281)	1396 (1105-1544)	1160; 1398

Age (years)	n	REE (MJ/d) estimated with **Mifflin et al 1990** Median (P5-P95)	REE (MJ/d) estimated with **Henry 2005** Median (P5-P95)	REE (MJ/d) estimated with **Müller et al 2004** Median (P5-P95)	REE (MJ/d) estimated with **Harris-Benedict (1919)** Median (P5-P95)	REE (MJ/d) estimated with **Schofield 1985** Median (P5-P95)	Lowest and highest median REE (MJ/d)	REE (kcal/d) estimated with **Mifflin et al 1990** Median (P5-P95)	REE (kcal/d) estimated with **Henry 2005** Median (P5-P95)	REE (kcal/d) estimated with **Müller et al 2004** Median (P5-P95)	REE (kcal/d) estimated with **Harris-Benedict (1919)** Median (P5-P95)	REE (kcal/d) estimated with **Schofield 1985** Median (P5-P95)	Lowest and highest median REE (kcal/d)
Women													
18 - 29	3589	5.6 (5.0-6.3)	5.6 (5.0-6.3)	5.7 (5.3-6.1)	5.9 (5.5-6.4)	5.7 (5.2-6.4)	5.6; 5.9	1341 (1201-1502)	1342 (1208-1509)	1351 (1267-1449)	1415 (1322-1520)	1368 (1245-1525)	1341; 1415
30 - 39	3866	5.3 (4.8-6.0)	5.4 (4.9-5.9)	5.5 (5.1-5.9)	5.7 (5.3-6.1)	5.5 (5.3-5.8)	5.3; 5.7	1277 (1147-1433)	1290 (1183-1418)	1306 (1230-1403)	1355 (1273-1460)	1324 (1267-1394)	1277; 1355
40 - 49	4727	5.1 (4.6-5.8)	5.4 (4.9-5.9)	5.3 (5.0-5.7)	5.5 (5.1-5.9)	5.5 (5.3-5.8)	5.1; 5.5	1221 (1091-1379)	1285 (1178-1407)	1269 (1191-1365)	1306 (1220-1412)	1321 (1264-1387)	1221; 1321
50 - 59	4066	4.8 (4.3-5.4)	5.3 (4.8-4.8)	5.1 (4.8-5.5)	5.2 (4.8-5.6)	5.5 (5.2-5.8)	4.8; 5.5	1151 (1016-1298)	1265 (1157-1384)	1223 (1141-1311)	1247 (1157-1344)	1311 (1253-1375)	1151; 1311
60 - 69	2806	4.6 (4.0-5.2)	4.9 (4.5-5.3)	5.0 (4.6-5.3)	5.0 (4.6-5.4)	5.0 (4.6-5.5)	4.6; 5.0	1102 (966-1232)	1164 (1068-1279)	1187 (1106-1266)	1202 (1109-1288)	1195 (1099-1309)	1102; 1202
70 - 79	915	4.3 (3.7-4.9)	4.8 (4.4-5.3)	4.8 (4.4-5.2)	4.8 (4.4-5.2)	5.0 (4.5-5.4)	4.3; 5.0	1028 (887-1182)	1154 (1054-1268)	1138 (1055-1231)	1139 (1046-1241)	1185 (1086-1298)	1028; 1185
80 - 89	88	4.0 (3.3-4.5)	4.7 (4.2-5.1)	4.6 (4.2-4.8)	4.5 (4.1-4.8)	4.8 (4.3-5.2)	4.0; 4.8	955 (796-1064)	1124 (1006-1222)	1091 (999-1155)	1078 (979-1149)	1155 (1037-1252)	955; 1155
90+	4	3.4 (3.4-3.9)	4.4 (4.4-4.8)	4.2 (4.2-4.5)	4.1 (4.1-4.4)	4.6 (4.6-4.9)	3.4; 4.6	813 (813-932)	1064 (1064-1144)	1000 (1000-1072)	971 (971-1052)	1095 (1095-1175)	813; 1095

The respective predictive equations based on body mass and height were used, where available (see Appendix 1). For Müller, the equation based on body mass for subpopulation 1 was used (Müller et al., 2004).

APPENDIX 9: COMPARISON OF MEASURED REE OF GISELA SUBJECTS (LAST AVAILABLE MEASUREMENTS) WITH REE CALCULATED WITH VARIOUS PREDICTIVE EQUATIONS

Women (n=386, 61-96 years, BMI 15.9-43.6)	**Median 5th-95th Percentile**					
REE (kJ/d) measured	5,590 4,516-7,092					
REE (kJ/d) predicted		**Bias**	**Upper limit of agreement**	**Lower limit of agreement**	**Accuracy (± 10 %) (n/%)**	**R^2**
Schofield (1985)	5,578 4,841-6,670	26	1,041	- 989	285/74 %	0.57
Müller et al. (2004)	5,305 4,438-6,554	- 263	749	- 1,275	280/73%	0.58
Henry (2005)	5,255 4,615-6,237	- 311	710	- 1,332	281/73 %	0.58
Harris-Benedict (1919)	5,215 4,410-6,342	- 364	648	- 1,376	259/67 %	0.57
Mifflin et al. (1990)	4,800 3,882-6,090	- 795	235	- 1,825	127/33 %	0.57
Men (n=165, 60-92 years, BMI 18.8-47.4)	**Median 5-95th Percentile**					
REE (kJ/d) measured	6,674 5,595-8,880					
REE (kJ/d) predicted		**Bias**	**Upper limit of agreement**	**Lower limit of agreement**	**Accuracy ± 10 %**	**R^2**
Müller et al. (2004)	6,814 6,062-8,052	43	1,284	- 1,199	118/72 %	0.57
Henry (2005)	6,596 5,663-7,918	- 203	1,081	- 1,487	117/71 %	0.53
Schofield (1985)	6,559 5,539-7,774	- 276	1,117	- 1,668	115/70 %	0.45
Harris-Benedict (1919)	6,250 5,186-7,903	- 494	779	- 1,767	96/58 %	0.56
Mifflin et al. (1990)	6,227 5,345-7,485	- 540	733	- 1,813	94/57 %	0.56

Bias = mean of differences (in kJ) of calculated REE vs. measured REE; Upper limit of agreement = Bias + (1.96 x SD); Lower limit of agreement = Bias – (1.96 x SD); Accuracy: estimated as the number and percentage of subjects that have an REE predicted by the equation within 10 % of the measured REE.

APPENDIX 10: SELECTED PREDICTIVE EQUATIONS FOR REE IN CHILDREN AND ADOLESCENTS

Prediction equations for REE for children and adolescents from Schofield (1985) using body mass (BM, in kg) and height (H, in m)

Age (years)	MJ/d (kcal/d) Boys	n	se	r	MJ/d (kcal/d) Girls	n	se	r
0-3	0.0007 BM + 6.349 H – 2.584 (0.167 BM + 1517.4 H –617.6)	162	0.243	0.97	0.068 BM + 4.281 H – 1.730 (16.25 BM + 1023.2 H – 413.5)	137	0.216	0.97
3-10	0.082 BM + 0.545 H + 1.736 (19.6 BM + 130.3 H + 414.9)	338	0.280	0.83	0.071 BM + 0.677 H + 1.553 (16.97 BM + 161.8 H + 371.2)	413	0.290	0.81
10-18	0.068 BM + 0.574 H + 2.157 (16.25 BM + 137.2 H + 515.5)	734	0.439	0.93	0.035 BM + 1.948 H + 0.837 (8.365 BM + 465 H + 200)	575	0.453	0.82

n, number of individuals; se, standard error; r, correlation coefficient of the linear regression

Prediction equations for REE for children and adolescents from Henry (2005) using body mass (BM, in kg) and height (H, in m)

Age (years)	MJ/d (kcal/d) Boys	n	se	r	MJ/d (kcal/d) Girls	n	se	r
0-3	0.118 BM + 3.59 H - 1.55 (28.2 BM + 859 H - 371)	246	0.246	0.96	0.127 BM + 2.94 H – 1.20 (30.4 BM + 703 H – 287)	201	0.232	0.96
3-10	0.0632 BM + 1.31 H + 1.28 (15.1 BM + 74.2 H + 306)[1]	289	0.322	0.84	0.0666 BM + 0.878 H + 1.46 (15.9 BM + 210 H + 349)	403	0.357	0.83
10-18	0.0651 BM + 1.11 H + 1.25 (15.6 BM + 266 H + 299)	863	0.562	0.86	0.0393 BM + 1.04 H + 1.93 (9.40 BM + 249 H + 462)	1,063	0.521	0.76

n, number of individuals; se, standard error; r, correlation coefficient of the linear regression
[1], likely error in the cited formula, so in this opinion the respective formula for MJ/d was used and the results for kcal/d obtained after conversion

APPENDIX 11: REFERENCE BODY HEIGHTS AND BODY MASSES FOR INFANTS, CHILDREN AND ADULTS

Infants and children

For the calculation of the average energy requirement reference body masses and reference body heights are required. It has previously been recommended to develop a database with reference body masses and heights representative for the total population in the EU (EFSA Panel on Dietetic Products Nutrition and Allergies (NDA), 2010). Concurrently, harmonised growth references for height, body mass and body mass index (BMI) at the EU level were calculated (van Buuren et al., 2012) using existing data available from the individual EU Member States and covering the period of 1990-2011. The coverage of the population in the EU was 90.1% for height-for-age, 87.5% for body mass-for-age, and 85.2% for BMI-for-age. The proposed harmonised EU growth references are used in this Opinion for the ages 1-17 years. Reference body heights and body masses for children aged 1-17 years are shown in Table 7.

Adults

For the report on nutrient and energy intakes for the European Community by the SCF (1993), weighted median body masses of European men and women derived from pooling of national data from a limited number of EU Member States were used. These data are relatively old and not necessarily representative for the newer EU Member States. For this Opinion, an attempt was made to gather more recent anthropometric data, to account for possible secular changes and the increase in size of the EU. For Bulgaria (Petrova and Angelova, 2006), Finland (Paturi et al., 2008), France (AFSSA, 2009), Germany (MRI, 2008a, 2008b), Ireland (Harrington et al., 2001; Kiely et al., 2001), Poland (Szponar et al., 2001; Szponar et al., 2003), Spain (AESAN) (Ortega et al., 2011), and United Kingdom (Henderson et al., 2002) individual data on measured body heights and body masses from representative surveys were already available to EFSA via the Comprehensive Food Consumption Database (Merten et al., 2011). Various other countries for which such data may be available were identified with the help of the European Commission Directorate General – SANCO and WHO Regional Office in Europe. Following a request for data submission, such data were received from The Netherlands (Health examination survey in the Netherlands 2009-2010) (Blokstra et al., 2011), Portugal (do Carmo et al., 2008), Slovakia (CINDI 2008) (Avdičová et al., 2005), Luxembourg (Alkerwi et al., 2010) and Czech Republic (HELEN Study: Health, Life Style and Environment 2004-2005) (Kratěnová et al., 2007). The overall population coverage, i.e. the number of inhabitants in these 13 EU Member States relative to all EU citizens is equal to 66-71 % for age groups between 18 and 69 years, 43 % for the age group 70-79 years and even lower for age groups 80-89 years and ≥ 90 years.

Weighting factors were used in order to take into account the population size of the respective country for which data were available. Weighting factors were obtained for both sexes by dividing, for each country, the population size of the age categories by the number of subjects included in the survey. Information on the population by country, age category and sex were extracted from the EUROSTAT website (http://epp.eurostat.ec.europa.eu) and are referred to 2010. Body masses were calculated for a BMI of 22 kg/m^2 and using measured body heights.

Median measured body heights and body masses as well as body masses for a BMI of 22 kg/m^2 based on data obtained in the 13 EU Member States are listed in Table 4.

APPENDIX 12A: RANGES OF AVERAGE REQUIREMENT (AR) FOR ENERGY FOR ADULTS BASED ON THE FACTORIAL METHOD AND PREDICTING REE WITH FIVE MOST USED EQUATIONS

Age (years)	Lowest median REE (kcal/d)	Highest median REE (kcal/d)	Range of AR at PAL = 1.4 (kcal/d)[1]	Range of AR at PAL = 1.6 (kcal/d)[1]	Range of AR at PAL = 1.8 (kcal/d)[1]	Range of AR at PAL = 2.0 (kcal/d)[1]	Range of AR at PAL = 2.2 (kcal/d)[1]	Range of AR at PAL = 2.4 (kcal/d)[1]
Men								
18-29	1,670	1,758	2,338 - 2,461	2,672 - 2,813	3,006 - 3,164	3,340 - 3,516	3,674 - 3,868	4,008 - 4,219
30-39	1,610	1,672	2,254 - 2,341	2,576 - 2,676	2,898 - 3,010	3,220 - 3,345	3,542 - 3,679	3,864 - 4,014
40-49	1,571	1,654	2,200 - 2,316	2,514 - 2,647	2,828 - 2,978	3,143 - 3,309	3,457 - 3,639	3,771 - 3,970
50-59	1,492	1,645	2,089 - 2,302	2,388 - 2,631	2,686 - 2,960	2,985 - 3,289	3,283 - 3,618	3,581 - 3,947
60-69	1,414	1,531	1,979 - 2,143	2,262 - 2,450	2,545 - 2,756	2,828 - 3,062	3,110 - 3,368	3,393 - 3,674
70-79	1,320	1,481	1,848 - 2,074	2,112- 2,370	2,376 - 2,666	2,640 - 2,962	2,904 - 3,258	3,169 - 3,555
Women								
18-29	1,338	1,415	1,873 - 1,981	2,140 - 2,264	2,408 - 2,547	2,675 - 2,830	2,943 - 3,113	3,210 - 3,396
30-39	1,277	1,355	1,787 - 1,898	2,043 - 2,169	2,298 - 2,440	2,553 - 2,711	2,809 - 2,982	3,064 - 3,253
40-49	1,221	1,321	1,710 - 1,849	1,954 - 2,114	2,198 - 2,378	2,442 - 2,642	2,687 - 2,906	2,931 - 3,170
50-59	1,151	1,311	1,612 - 1,835	1,842 - 2,097	2,072 - 2,359	2,303 - 2,621	2,533 - 2,883	2,763 - 3,145
60-69	1,101	1,202	1,542 - 1,682	1,762 - 1,923	1,983 - 2,163	2,203 - 2,403	2,423 - 2,644	2,644 - 2,884
70-79	1,028	1,185	1,439 - 1,659	1,644 - 1,896	1,850 - 2,133	2,055 - 2,370	2,261 - 2,607	2,466 - 2,844

[1]Based on lowest and highest median REE (see Appendix 8).

APPENDIX 12B: RANGES OF AVERAGE REQUIREMENT (AR) FOR ENERGY FOR CHILDREN AND ADOLESCENTS BASED ON THE FACTORIAL METHOD AND PREDICTING REE WITH TWO PREDICTIVE EQUATIONS

Age (years)	REE (kcal/d) (Henry)	REE (kcal/d) (Schofield)	Range of AR at PAL = 1.4 (kcal/d)	Range of AR at PAL = 1.6 (kcal/d)	Range of AR at PAL = 1.8 (kcal/d)	Range of AR at PAL = 2.0 (kcal/d)	Range of AR at PAL = 2.2 (kcal/d)	Range of AR at PAL = 2.4 (kcal/d)
Boys								
1	570	539	762 - 806	871 - 921				
2	738	712	1,007 -1,044	1,151 - 1,193				
3	830	829	1,172 -1,174	1,339 -1,341				
4	888	884	1,249 -1,256	1,428 -1,436	1,606 -1,615	1,785 -1,794	1,963 -1,974	
5	942	935	1,322 -1,332	1,511 -1,522	1,700 -1,712	1,889 -1,903	2,078 -2,093	
6	996	988	1,398 -1,409	1,597 - 1,610	1,797 -1,811	1,997 -2,013	2,196 -2,214	
7	1,059	1,052	1,487 -1,497	1,700 -1,711	1,912 -1,925	2,125 -2,139	2,337 -2,353	
8	1,126	1,121	1,585 -1,592	1,811 -1,819	2,037 -2,046	2,264 -2,274	2,490 -2,501	
9	1,191	1,191	1,683 -1,684	1,924 -1,925	2,164 -2,165	2,405 -2,406	2,645 -2,647	
10	1,196	1,257	1,691 -1,777	1,933 - 2,031	2,174 -2,285	2,416 -2,539	2,658 -2,793	2,899 -3,047
11	1,264	1,321	1,788 - 1,868	2,043 – 2,135	2,298 -2,401	2,554 -2,668	2,809 -2,935	3,065 -3,202
12	1,345	1,397	1,902 - 1,976	2,174 - 2,258	2,445 -2,540	2,717 -2,822	2,989 -3,104	3,260 -3,387
13	1,444	1,491	2,041 - 2,108	2,333 - 2,409	2,625 -2,710	2,916 -3,011	3,208 -3,313	3,500 -3,614
14	1,555	1,598	2,199 - 2,259	2,513 - 2,582	2,828 -2,905	3,142 -3,228	3,456 -3,550	3,770 -3,873
15	1,670	1,709	2,362 - 2,416	2,699 – 2,761	3,036 -3,107	3,374 -3,452	3,711 -3,797	4,048 -4,142
16	1,761	1,797	2,489 - 2,542	2,845 - 2,905	3,201 -3,268	3,556 -3,631	3,912 -3,994	4,268 -4,357
17	1,819	1,856	2,572 - 2,624	2,940 - 2,999	3,307 -3,374	3,675 -3,748	4,042 -4,123	4,409 -4,498
Girls								
1	525	503	711 - 742	813 - 848				
2	688	668	945 - 973	1,080 -1,112				
3	775	767	1,084 -1,096	1,239 -1,253				
4	826	816	1,154 -1,168	1,319 -1,335	1,483 -1,502	1,648 -1,668	1,813 -1,835	
5	877	866	1,224 -1,239	1,399 -1,417	1,574 -1,594	1,749 -1,771	1,924 -1,948	
6	928	917	1,297 -1,312	1,482 -1,500	1,667 -1,687	1,852 -1,875	2,037 -2,062	
7	984	973	1,376 -1,392	1,572 -1,591	1,769 -1,790	1,956 -1,989	2,162 -2,187	

Age (years)	REE (kcal/d) (Henry)	REE (kcal/d) (Schofield)	Range of AR at PAL = 1.4 (kcal/d)	Range of AR at PAL = 1.6 (kcal/d)	Range of AR at PAL = 1.8 (kcal/d)	Range of AR at PAL = 2.0 (kcal/d)	Range of AR at PAL = 2.2 (kcal/d)	Range of AR at PAL = 2.4 (kcal/d)
8	1,045	1,034	1,461 -1,477	1,670 -1,688	1,879 -1,899	2,088 -2,110	2,297 -2,321	
9	1,107	1,097	1,551 -1,566	1,773 -1,790	1,994 -2,013	2,216 -2,237	2,437 -2,461	
10	1,125	1,133	1591 -1,602	1,818 -1,831	2,046 -2,059	2,273 -2,288	2,500 -2,517	2,728 -2,746
11	1,181	1,198	1669 -1,694	1,908 -1,936	2,146 -2,177	2,385 -2,419	2,623 -2,661	2,862 -2,903
12	1,240	1,266	1754 -1,790	2,004 -2,046	2,255 -2,301	2,505 -2,557	2,756 -2,813	3,006 -3,069
13	1,299	1,331	1837 -1,882	2,099 -2,150	2,361 -2,419	2,624 -2,688	2,886 -2,957	3,149 -3,226
14	1,346	1,381	1903 -1,952	2,175 -2,231	2,447 -2,510	2,719 -2,789	2,991 -3,068	3,262 -3,347
15	1,379	1,415	1950 -2,001	2,228 -2,287	2,507 -2,573	2,786 -2,859	3,064 -3,145	3,343 -3,430
16	1,398	1,434	1,977 -2,028	2,259 -2,318	2,542 -2,608	2,824 -2,898	3,107 -3,187	3,389 -3,477
17	1,409	1,446	1,992 -2,044	2,277 -2,336	2,562 -2,628	2,846 -2,920	3,131 -3,212	3,416 -3,504

APPENDIX 13: SUMMARY OF AVERAGE REQUIREMENT (AR) FOR ENERGY EXPRESSED IN KCAL/D

Summary of Average Requirement (AR) for energy for adults

Age (years)	REE[1] (kcal/d)	AR at PAL = 1.4 (kcal/d)	AR at PAL = 1.6 (kcal/d)	AR at PAL = 1.8 (kcal/d)	AR at PAL = 2.0 (kcal/d)
Men					
18-29	1,670	2,338	2,672	3,006	3,340
30-39	1,610	2,254	2,576	2,898	3,220
40-49	1,589	2,224	2,542	2,860	3,177
50-59	1,573	2,202	2,517	2,832	3,146
60-69	1,438	2,013	2,301	2,588	2,876
70-79	1,417	1,984	2,267	2,550	2,834
Women					
18-29	1,338	1,873	2,140	2,408	2,675
30-39	1,290	1,806	2,064	2,321	2,579
40-49	1,284	1,798	2,055	2,312	2,569
50-59	1,265	1,771	2,024	2,277	2,529
60-69	1,163	1,628	1,861	2,093	2,326
70-79	1,153	1,614	1,844	2,075	2,305

[1]REE, resting energy expenditure predicted with the equations of Henry (2005) using body mass and height. Because these have overlapping age bands (18-30 years, 30-60 years, ≥60 years) (see Appendix 1), the choice of equation is ambiguous at the age boundaries. The REE equations for 18-30 year-olds are used for adults aged 18-29 years, the equations for 30-60 year-olds are used for adults aged 30-39, 40-49, and 50-59 years, and the equations for ≥60 year-olds are used for adults aged 60-69 and 70-79 years.

Summary of Average Requirement (AR) for energy for infants

Age	AR (kcal/d)		AR (kcal/kg BM per day)	
	Boys	**Girls**	**Boys**	**Girls**
7 months	635	575	76	75
8 months	660	600	77	76
9 months	690	625	77	76
10 months	725	655	79	77
11 months	740	675	79	77

[1] 50th percentile of WHO Growth Standards (WHO Multicentre Growth Reference Study Group, 2006)

Summary of Average Requirement (AR) for energy for children and adolescents

Age (years)	REE[2] (kcal/d)	AR[3] at PAL[4] = 1.4 (kcal/d)	AR[3] at PAL = 1.6 (kcal/d)	AR[3] at PAL = 1.8 (kcal/d)	AR[3] at PAL = 2.0 (kcal/d)
Boys[1]					
1	570	806			
2	738	1,044			
3	830	1,174			
4	888	1,256	1,436	1,615	
5	942	1,332	1,522	1,712	
6	996	1,409	1,610	1,811	
7	1,059	1,497	1,711	1,925	
8	1,126	1,592	1,819	2,046	
9	1,191	1,684	1,925	2,165	
10	1,196		1,933	2,174	2,416
11	1,264		2,043	2,298	2,554
12	1,345		2,174	2,445	2,717
13	1,444		2,333	2,625	2,916
14	1,555		2,513	2,828	3,142
15	1,670		2,699	3,036	3,374
16	1,761		2,845	3,201	3,556
17	1,819		2,940	3,307	3,675
Girls[1]					
1	525	742			
2	688	973			
3	775	1,096			
4	826	1,168	1,335	1,502	
5	877	1,239	1,417	1,594	
6	928	1,312	1,500	1,687	
7	984	1,392	1,591	1,790	
8	1,045	1,477	1,688	1,899	
9	1,107	1,566	1,790	2,013	
10	1,125		1,818	2,046	2,273
11	1,181		1,908	2,146	2,385
12	1,240		2,004	2,255	2,505
13	1,299		2,099	2,361	2,624
14	1,346		2,175	2,447	2,719
15	1,379		2,228	2,507	2,786
16	1,398		2,259	2,542	2,824
17	1,409		2,277	2,562	2,846

[1] Based upon the 50th percentile of harmonised curves for body masses and heights of EU children (van Buuren et al., 2012)
[2] REE, resting energy expenditure computed with the predictive equations of Henry. Because the equations of Henry have overlapping age bands (0-3, 3-10, 10-18 years), the choice of equation is ambiguous at the age boundaries. The REE equation for 3-10 year-olds is used for the 3 year-olds and the equation for 10-18 year-olds is used for those aged 10 years.
[3] Taking into account a coefficient of 1.01 for growth.
[4] PAL, physical activity level

Summary of Average Requirement (AR) for energy for pregnant and lactating women (in addition to the AR for non-pregnant women)

	AR (kcal/d)
Pregnant women	
1st trimester	+70
2nd trimester	+260
3rd trimester	+500
Lactating women 0-6 months *post partum*	+500

GLOSSARY AND ABBREVIATIONS

AESAN	Agencia Española de Seguridad Alimentaria y Nutrición
AFSSA	Agence Française de Sécurité Sanitaire des Aliments
AR	Average Requirement
ATP	Adenosin-triphosphate
BEE	Basal energy expenditure
BM	Body mass
BMI	Body mass index
BMR	Basal metabolic rate
cal	calorie
CINDI	Countrywide Integrated Noncommunicable Diseases Intervention
COMA	Committee on Medical Aspects of Food Policy
CV	Coefficient of variation
D-A-CH	Deutschland- Austria- Confoederatio Helvetica
DIT	Diet-induced thermogenesis
DLW	Doubly-labelled water
DoH	Department of Health
DRV	Dietary Reference Value
EAR	Estimated average requirement
EC	European Commission
EEPA	Energy expenditure of physical activity
EER	Estimated energy requirement
EFSA	European Food Safety Authority
EU	European Union
FAO	Food and Agriculture Organisation
FFM	Fat-free mass
FQ	Food quotient

FM	Fat mass
GE	Gross energy
GISELA	Giessener Senioren Langzeitstudie
HELEN	Health, Life Style and Environment
HR	Heart rate
IE	Ingested energy
IoM	U.S. Institute of Medicine of the National Academy of Sciences
LGA	Large-for-gestational-age
ME	Metabolisable energy
MJ	Mega-joule
mo	month
MRI	Max Rubner Institut
NEAT	Non-exercice activity thermogenesis
NME	Net metabolisable energy
NNR	Nordic Nutrition Recommendations
OPEN	Observing Protein and Energy Nutrition
PA	Physical activity
PAL	Physical activity level
PAR	Physical activity ratio
PRI	Population reference intake
REE	Resting energy expenditure
RQ	Respiratory quotient
SACN	Scientific Advisory Committee on Nutrition
SCF	Scientific Committee for Food
SD	Standard deviation
se	Standard error
s.e.e.	Standard error of estimate
SEE	Sleeping energy expenditure

SGA	Small-for-gestational-age
SI	International System of Units
TEE	Total energy expenditure
TEF	Termic effect of food
UK	United Kingdom
UNU	United Nations University
US	United States
VCO_2	Carbon dioxide production
VO_2	Oxygen consumption
WHO	World Health Organisation
y	year