# Evaluation of dietary reference values for energy

No. 2022/19A, The Hague, 16 August 2022

Background document to:
Dietary reference values for energy
2022/19, The Hague, 16 August 2022

Health Council of the Netherlands

# Contents

# 1 Introduction

This report serves as the background document for the advisory report *Dietary reference* values for energy (in Dutch: Voedingsnormen voor energie), which has been prepared by the Committee on Nutrition of the Health Council of the Netherlands (HCNL).[1,2]

The Council previously decided that reference values should ideally be harmonised throughout the European Union (EU). Based on that view, the Council is evaluating the dietary reference values (DRVs) that the European Food Safety Authority (EFSA) published between 2010 and 2019, to determine whether these could also be applied to the Netherlands. Three advisory reports on this topic have been issued so far.[3-5] In the current advisory report, the Committee evaluated whether the DRVs for energy set by EFSA in 2013[6] could be adopted by the Netherlands.

In this background document, EFSA's DRVs for energy are presented and discussed, in combination with the current Dutch DRVs for energy that were derived by HCNL in 2001[7] and the DRVs set by the Food and Agriculture Organisation of the United Nations (FAO)/World Health Organisation (WHO)/United Nations University (UNU),8 the Institute of Medicine (IoM)[9], the Nordic countries,[10] the German-speaking DACH-countries (Deutschland [Germany], Austria and Confoederatio Helvetica [Switzerland])[11,12] and the Scientific Advisory Committee on Nutrition (SACN; United Kingdom).[13] DRVs for energy were set for the following groups: adults, infants, children, pregnant women and lactating women.

# 2 Background information on energy

## 2.1 Energy requirement

The energy requirement is the amount of energy that must be obtained from food to balance energy expenditure in order to maintain body mass, body composition and a level of physical activity that is consistent with long-term good health. In addition, infants, children and pregnant women need energy for tissue growth and lactating women need energy for the production of breast milk in order to maintain their own good health and that of their child.

Under conditions of steady body weight, body composition and physical activity, energy intake balances energy expenditure, so that the average energy requirement may in theory be derived by estimating either energy intake or energy expenditure. However, the measurement error when estimating energy intake is generally higher than with energy expenditure.[14] Therefore, energy requirements are generally based on estimates of energy expenditure nowadays.

## 2.2 Components of total energy requirement

The total energy expenditure (TEE) is the energy expended over a period of 24 hours, and is an indicator of the total daily energy requirement. TEE comprises the following components: the basal energy expenditure (BEE), the energy expenditure of physical activity (EEPA) and the thermic effect of food (TEF). Occasionally, cold-induced thermogenesis should be taken into account. TEE does not include the energy that is deposited as protein and fat in growing tissues, for example in children or pregnant women.

The basal energy expenditure (BEE) is the energy needed to maintain the basic physiological functions of the body that are essential for life. BEE represents the energy expenditure under conditions that exclude the influence of the external environment, such as physical movement, food, drugs, cold or heat.[15] Hence, BEE is determined when the body is at rest and under strictly defined conditions, which include: after overnight fasting (10-14 hours of food deprivation), avoidance of strenuous exercise during the previous day (or eight hours of physical rest), awake, supine, motionless, resting comfortably, free of emotional stress and in a thermoneutral environment.[6,8,15] Note that the BEE is not the same as the energy expenditure during sleep (SEE). SEE is generally somewhat lower (5 to 10%) than BEE as it does not include the energy expenditure associated with arousal.[16]

The *resting energy expenditure (REE)* is the energy expended when the body is at rest. EFSA, like many organisations, views REE as a proxy for BEE. REE is measured under less stringent conditions than BEE and may be somewhat higher than BEE (up to 20%,[6,9,10] but usually the difference is much smaller), due to, for example, a shorter period of fasting or physical rest before the REE measurement or a non-thermoneutral environment. It is very complex to fulfil the conditions for measuring BEE, and therefore REE is most frequently measured.

The *energy expenditure of physical activity (EEPA)* includes the energy expended for all body movements produced by skeletal muscles, which encompass all obligatory and discretionary activities in daily live.

The *thermic effect of food (TEF)*, also called diet-induced thermogenesis, is the energy needed for digestion, absorption, transport, interconversion and deposition (or storage) of nutrients. These metabolic processes increase the REE. The estimated increase in energy expenditure is equivalent to approximately 10 per cent of the energy intake of the food consumed (based on a mixed diet).[17] Energy expended for the muscular work involved in eating is not part of the TEF, but is part of the EEPA.

*Cold-induced thermogenesis* is the production of heat in response to environmental temperatures below thermoneutrality. 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.

EEPA is the component of energy expenditure with the highest variability.[18,19] EEPA may vary greatly between individuals with different levels of physical activity, and EEPA may also vary from day to day in one and the same individual. EEPA is generally expressed as the physical activity level (PAL) or PAL value, which is usually calculated as the ratio of TEE to REE over a period of 24 hours. Because REE rather than BEE is mainly used to estimate PAL values, the PAL value not only includes the energy expenditure due to physical activity, but also the thermic effect of food as well as cold-induced thermogenesis.

## 2.3 Assessment of energy expenditure

### 2.3.1 Commonly used methods for measuring energy expenditure

Indirect calorimetry and the doubly-labelled water (DLW) method are the most commonly used methods for assessing energy expenditure.

*Indirect calorimetry* measures the use of $O_2$ and the production of $CO_2$ by the body, from which energy expenditure can be estimated. Different indirect calorimetry systems offer different possibilities. For instance, a whole room calorimeter is used to measure TEE under laboratory conditions, whereas the ventilated hood system is used to measure a TEE component, such as BEE, REE or EEPA during a standardised activity or TEF after a standardised meal.

The *doubly-labelled water (DLW) method* (in Dutch: dubbelgemerktwater-methode) can be used to determine TEE in free-living individuals. The individual ingests a known amount of doubly-labelled water, which is water containing the stable isotopes deuterium ($^2H$) and $^{18}O$. These isotopes are gradually eliminated from the body; $^2H$ through water and $^{18}O$ through water and $CO_2$. Within two weeks, the isotopes are measured in body fluids (urine, saliva, plasma). The production of $CO_2$ by the body is then estimated from the difference in the elimination of the two isotopes. Estimating TEE from $CO_2$ production relies on several assumptions.[6] The main advantages of the DLW method compared to indirect calorimetry are: 1) it yields estimates of energy expenditure over a biologically meaningful period of time; 2) it captures the energy expenditure of all kinds of activities; 3) it can be measured in individuals leading their usual lives; and 4) the measurement of TEE by the DLW method combined with a measurement or estimation of REE permits the calculation of the PAL value.

It is assumed that TEE in normal living conditions is best estimated using the DLW method,[20] because this method enables long-term measurements and preserves usual behaviour better than measurements taken in room calorimeters.

Other methods to estimate energy expenditure include heart rate monitoring and accelerometry. These methods have been less frequently used (so far) for this purpose and are therefore not further discussed in this document.

#### 2.3.2 Equations to predict resting energy expenditure

Measuring REE requires specialised laboratory facilities, time and money. Therefore, prediction equations for REE have been developed from regression analyses of data from individuals whose REE was measured by indirect or direct calorimetry. These equations enable the REE to be predicted based on more easily measurable parameters such as sex, age, body weight and height. Such equations are easy to apply and widely used. Multiple (sets of) prediction equations for REE are available. **Annex A** (Tables A1 to A3) shows the prediction equations for REE used in the EFSA report and in the other reports that the Committee considered for its evaluation. A description of the databases from which these prediction equations were developed is provided in **Annex B**.

It is important to note that these prediction equations for REE can provide an estimation of an individual's energy requirement, but with a (large) chance of deviations from the true requirement. These prediction equations are considered sufficiently accurate when used for the purpose of setting DRVs for energy at group level.

Based on information on an individual's physical activity level, an assumption may be made about the PAL value. An individual's TEE may then be estimated by multiplying the predicted REE by the assumed PAL value. A similar approach can be used to estimate the TEE at group level (by using the assumed PAL value of the group of interest). Again, for the TEE at group level this method provides a good approximation, whereas for individuals, the estimated TEE may deviate substantially from the true value.

# 3 Methodology

For the purpose of harmonising DRVs throughout the EU, the Health Council of the Netherlands is evaluating whether the DRVs set by EFSA could also be applied to the Netherlands. Three advisory reports on this topic have been issued so far.[3-5] The procedure for evaluating EFSA's DRVs that was developed for those advisory reports was used as the basis for deriving the DRVs for energy in this report.

## 3.1 Starting point of evaluation

The starting point of this evaluation was to adopt EFSA's DRVs for use in the Netherlands, unless there were major objections against doing so. Major objections could relate to the nutritional context of the Netherlands or the scientific basis used by EFSA (i.e. the evaluated research and the argumentation used by EFSA to derive DRVs). In case of major objections against the EFSA's reference values or approach, the HCNL's Committee on Nutrition has derived alternative values, which should preferably be harmonised with a report of another organisation (further described below). To this end, the Committee evaluated the research and line of reasoning that EFSA used to establish DRVs for energy for each population group. In doing so, it compared EFSA's DRVs and argumentation with those of the other organisations. Because the key principle is harmonisation with EFSA, the Committee did not update the literature. Any literature provided by the experts from the Committee has, however, been taken into account in the evaluation.

## 3.2 Comparison of seven national and international reports

The Committee evaluated the DRVs for energy set by EFSA in 2013, in combination with the current DRVs for energy set by HCNL (2001) and five other reports of national and international organisations that established DRVs for energy:

- S*cientific Opinion on \Dietary Reference Values for energy* by EFSA, 2013[6]
- *Dietary Reference Intakes: energy, proteins, fats and digestible carbohydrates* by the Health Council of the Netherlands (HCNL), 2001[7]
- *Human energy requirements* by the Food and Agriculture Organisation of the United Nations (FAO), World Health Organisation (WHO) and United Nations University (UNU), 2004[8]
- *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids* by the Institute of Medicine (IoM; known as the National Academy of Medicine [NAM] since 2015), 2005[9]
- *Nordic Nutrition Recommendations 2012* by the Nordic Council of Ministers (NCM), 2014[10]
- *Referenzwerte für die Nährstoffzufuhr* by the German-speaking DACH countries (Deutschland [Germany], Austria and Confoederatio Helvetica [Switzerland]), 2015[11,12]

- *Dietary reference values for energy* by the Scientific Advisory Committee on Nutrition (SACN) from the United Kingdom, 2011[13]

These reports were selected because they either represent the Dutch reference values that will remain in force until the publication of the present advisory report (HCNL, 2001[7]), thoroughly describe the derivation of the reference values for energy intended for use in various countries (FAO/WHO/UNU, 2004[8] and IoM, 2005[9]) or derive reference values for energy for large European regions (NCM, 2014[10] and DACH, 2015[11,12]). Reports by SACN have not been considered by the Committee in previous evaluations on DRVs, because they are aimed at application in one state and not large regions. However, for the current advisory report, the Committee additionally evaluated the advisory report on energy by SACN[13] because EFSA often referred to this report when deriving its DRVs for energy.

In its report, EFSA described each of the aforementioned reports, except for the 2014 report by NCM[10] and the 2015 report by DACH.[11,12] These reports were probably not yet available at the time of EFSA's evaluation and thus, EFSA evaluated the NCM's previous report from 2004[21] and DACH's previous report from 2012.[22]

### 3.3 Age groups and categories

The Committee previously decided to adopt EFSA's terminology, definitions and age categorisation.[3-5] This means that the Committee set DRVs according to sex and age groups (i.e. infants, children and adults from various age categories), and derived separate DRVs for pregnant women and lactating women. The Committee made two adjustments to EFSA's age categorisation; one regarding the age groups of adults and one regarding the age groups of infants.

The highest age group defined by EFSA is 70-79 years. EFSA has not derived an AR for adults aged 80 years and over due to a lack of anthropometric data, such as body weight and height, for this oldest group. The Committee replaces the highest age group used by EFSA with a group aged 70 years and older, because there are reference values available for body weight and height for Dutch adults aged 70 to 90 years. The Committee decides to expand the highest age group instead of adding additional ones. Less data is available for adults aged 80 years and over, so the REE, physical activity level, height and body weight are less certain. Consequently, the estimate of the AR of that group would be less certain if these data were used (see 4.1.3). The category of ≥70 years corresponds to the Council's previous report on DRVs for proteins (2021).[4]

EFSA derived an AR for infants aged 7, 8, 9, 10 and 11 months, and not for those aged 0 up to and including 6 months. Unlike EFSA, the Committee also determines an AR for infants aged 6 months (see 4.2.2) since it is recommended to offer babies complementary (solid) foods in addition to breast milk or formula, starting from the age of 6 months.

For the purpose of clarity and readability, the term 'adults' is used when speaking of adult men and non-pregnant, non-lactating women. The term 'non-pregnant, non-lactating women' is used to refer to non-pregnant, non-lactating adult women of childbearing age.

### 3.4 Average requirements and additional requirements

One type of DRV will be established for energy: the average requirement (AR). The reason for this is that, for energy, there is no intake value that applies to (nearly) all healthy individuals since the individual energy requirement varies greatly among different people due to differences in physical activity, body weight and body composition. If a person's average energy intake deviates from his or her requirement, this will lead to a weight change, which may not be desired. Thus, a person's energy intake should correspond to his or her individual energy requirement, and not to the AR. That is also why the AR for energy has little relevance at the individual level. Yet, the AR is relevant for applications at the group level. As the AR is the single type of DRV derived for energy, the term 'AR' will be used instead of 'DRV' in the remainder of this background document.

Both EFSA and the other organisations derived ARs for energy for the groups of infants, children and adults. For pregnant women and lactating women, there are three ways to derive a requirement:[5] 1) a specific reference value, or 'total requirement', is derived based on research in either pregnant or lactating women; 2) an 'additional requirement' during pregnancy or lactation is derived, which is added to the AR of non-pregnant, non-lactating women to obtain the reference value for either pregnant women or lactating women (additive model); 3) the requirement of pregnant women or lactating women is similar to the requirement of non-pregnant, non-lactating women.

The Committee rounds the final ARs and additional requirements for energy off to the nearest 10 kcal. Rounding prevents false accuracy and rounded numbers are more useful in communication and in practice. The tables showing the final ARs and additional requirements for the Dutch include both the rounded and unrounded values (in brackets).

### 3.5 Reference weights

When calculating the reference body weights, the Committee previously decided to adopt EFSA's approach but to use Dutch (instead of European) figures. With regard to the DRV in kcal or kilojoules (kJ) per day, it has decided to use the Dutch figures for height, because the Dutch are on average taller (and thus slightly heavier) than other Europeans. Details regarding the calculation of these reference values are provided in the Council's advisory report *Dietary reference values for proteins.*[4] A summary of the datasets used and argumentation is given below.

*Adults*
The Committee used two representative samples from the Netherlands to determine the average height of adult Dutch people.[23-26] To calculate corresponding healthy body weights, the Committee used a healthy body mass index (BMI) of 22 $kg/m^2$ for the age group of 18 to 50 years, of 23 $kg/m^2$ for the age group of 50 to 70 years and of 24 $kg/m^2$ for the age group of over 70 years.

*Infants and children*
Body heights from the Fifth Growth Study[27] were combined with body weights from the Third Growth Study, based on weight-for-height growth charts[28,29] and additional details as provided by TNO Healthy Living, the Netherlands. Data from the Third Growth Study instead of the most recent Fifth Growth Study were used to determine body weights, because the prevalence of childhood obesity has increased over the years and thus, energy recommendations would be too high if they were based on the most recently measured body weights.

# 4 Derivation of DRVs for energy

In this chapter, the Committee summarises the approaches used by EFSA and the other organisations for deriving the ARs for energy, and the additional requirements for pregnant women and lactating women. It indicates on which points the approaches correspond with each other and where the approaches differ from each other and especially from EFSA, and it describes any considerations made by EFSA and the other organisations. The evaluation ends with the Committee's argumentation for the approach used to derive the ARs and additional requirements for energy for the Netherlands. The final values are summarised in a table at the end of each section.

## 4.1 Adults (18 years and older)

**Table 1** provides an overview of the criteria on which EFSA and the other organisations based their ARs for energy for adults.

### 4.1.1 EFSA's approach and comparison with other organisations

*General approach*

EFSA determined the AR for adults by multiplying the predicted REE by a PAL value. EFSA predicted the REE using the prediction equations of Henry (2005).[15] EFSA derived ARs for four levels of physical activity (four PAL values) that were assumed to reflect low active (sedentary), moderately active, active and very active lifestyles: 1.4, 1.6, 1.8 and 2.0, respectively. EFSA used PAL values with equal (0.2-step) intervals within the range of PAL values that were observed in DLW studies in free-living subjects and are consistent with a sustainable lifestyle (i.e. a lifestyle that can be maintained for a long period of time; most people can only sustain a PAL value above 2.4 for a short time).

All organisations, except for IoM, used the same approach as EFSA for deriving the ARs for adults, i.e. by determining the product of the predicted REE and a PAL value. IoM predicted TEE instead of REE. It compiled a dataset of DLW studies in 407 adults with a healthy BMI and developed sex-specific prediction equations for TEE based on age, body weight, height and PAL value. It specified ARs for four categories of physical activity, by using physical activity coefficients corresponding to one of four categories of physical activity. For this purpose, IoM determined individual PAL values using measured BEE and measured TEE of the individuals in the DLW database. Individuals were then assigned to one of the four categories of physical activity and, subsequently, corresponding coefficients were calculated using regression analysis. IoM itself reported that the DLW data they collected were not from randomly selected individuals and were not representative of the US and Canadian populations. IoM argued, however, that these data provided the best information available at that moment.

*Prediction equations to estimate REE*

For the prediction of REE, EFSA, NCM and SACN used the prediction equations developed by Henry (2005),[15] HCNL and FAO/WHO/UNU used the prediction equations developed by Schofield (1985),[30] and the DACH countries used those developed by Müller et al. (2004;[31] based on a German dataset).

*PAL values used to estimate the AR*

EFSA's approach of deriving multiple ARs (per sex and age group) according to various PAL values with equal intervals is similar to the approaches of NCM and DACH, although NCM used three (1.4, 1.6 and 1.8) instead of four PAL values (EFSA additionally used a PAL value of 2.0). FAO/WHO/UNU and IoM also applied PAL values that correspond to certain lifestyle categories, but the PAL values assigned to the lifestyle categories were different:

- FAO/WHO/UNU defined three (sustainable) lifestyle categories and corresponding ranges of PAL values based on a meta-analysis of DLW studies (sedentary or low active: 1.40-1.69, active or moderately active: 1.70-1.99, vigorously active: 2.00-2.40).[32] FAO/WHO/UNU recommended using the midpoint PAL value of the lifestyle category corresponding to the population of interest for calculating the AR, but used PAL values of 1.45, 1.60, 1.75, 1.90, 2.05 and 2.20 for the sample calculations in its report. These values differ from those applied by EFSA.
- Although IoM used a different approach to establish the AR, it did use four categories of physical activity with corresponding ranges of PAL values (sedentary: 1.0-1.4, low active: 1.4-1.6, active: 1.6-1.9, very active: 1.9-2.5).[9] Considering the midpoint of the range of PAL values of each category (1.2, 1.5, 1.75 and 2.2), IoM applied different values compared to EFSA.
- SACN also defined ARs for multiple levels of physical activity, which were determined according to the 25$^{th}$, 50$^{th}$ and 75$^{th}$ percentile of the observed distribution of PAL in two DLW studies:[33-35] 1.49, 1.63 and 1.78, respectively. These values were assumed to reflect the "population activity level" (50$^{th}$ percentile) and the activity levels of those thought to be less (25$^{th}$) or more (75$^{th}$) active than average.

In 2001, HCNL determined one PAL value (per sex and age group) consistent with the average low level of physical activity in the Netherlands. So, except for HCNL in 2001, none of the organisations specified a single AR according to the PAL value that best fit the population to be advised.

All organisations used DLW data to (directly or indirectly) select PAL values, although the datasets on which the PAL values were based differed from each other. Table C1 in **Annex C** provides an overview and brief description of the datasets from which the organisations derived their PAL values.

### 4.1.2 EFSA's considerations

EFSA rejected the approach used by IoM for estimating TEE directly using prediction equations derived from DLW studies, with which TEE is predicted based on age, body weight, height and physical activity. EFSA deemed the available DLW datasets insufficient for determining such prediction equations, because: 1) the study populations in the available datasets may not be representative of the (European) adult population; 2) the DLW studies were relatively small; and 3) the available DLW data were limited or lacking for some age groups (i.e. 18-29 y and >70 y). The estimation of TEE from the product of predicted REE and (on DLW data based) PAL values is supported by larger datasets. Therefore, EFSA used this approach.

EFSA stated that the validity of five prediction equations[15,30,31,36,37] (**Annex A**) is similar for estimating REE in healthy Europeans and that none of these equations seem to provide a significantly better estimate of REE than any of the other equations. The differences in (median) predicted REE based on these five equations, within a sex and age group, were calculated to range between 54 and 162 kcal/d and between 3 and 13%. To illustrate, the median predicted REE in women aged 18-29 years ranged from 1342 kcal/d based on the equations developed by Mifflin et al.[37] to 1416 kcal/d based on the Harris & Benedict equations[36] (difference: 74 kcal (5%)). In men aged 70-79 years, the median predicted REE ranged from 1320 kcal/d based on the Harris & Benedict equations[36] to 1482 kcal/d based on the equations developed by Müller et al.[31] (difference: 162 kcal (11%)). The difference in predicted REE between the equations became greater with increasing age. EFSA decided to derive its energy requirements for adults on the basis of the equations developed by Henry (2005),[15] because these equations – also called the Oxford equations – are based on the largest underlying dataset, i.e. with the largest number of participants, nationalities and age categories.

For similar reasons as those for not using DLW data to derive TEE, EFSA also did not directly apply the PAL values that were estimated in DLW studies by dividing measured TEE by measured/predicted REE. EFSA applied PAL values with equal intervals within the observed range of physical activity levels consistent with a sustainable lifestyle (from DLW data): 1.4, 1.6, 1.8 and 2.0. This resulted in four ARs for energy per sex and age group.

EFSA noted that the range of PAL values is considerable between individuals with similar lifestyles, and that only a weak relationship has been reported in the literature between lifestyle or self-reported physical activity and PAL value.[13,38] This can be due to, for example, variations in spontaneous physical activity (i.e. all body movements associated with activities of daily living, change of posture and fidgeting[39,40]) or, conversely, variations in the way that activity levels are reduced or not after intense activity.[41]

EFSA did not derive an AR for adults aged 80 years and older due to a lack of anthropometric data, such as height and weight, for this oldest group.

### 4.1.3 The Committee's conclusions for the Netherlands

Although the Committee did not systematically update the literature, it is aware of the existence of a dataset assembled by the International Atomic Energy Agency (IAEA) that contains approximately 6500 measurements of TEE that were obtained using the DLW method from individuals aged 8 days to 95 years from over 20 countries. In a recent publication, the IAEA described (changes in) energy expenditure over the course of life and presented two sets of prediction equations for TEE (for four age groups): one set based on age, sex and body weight and the other on age, sex, fat mass and fat-free mass.[42,43] The Committee considers this publication, in addition to the other seven reports, in determining its approach for deriving the average energy requirement for adults.

The Committee decides to use prediction equations for REE and decides against using prediction equations for TEE (from IoM or IAEA), for the following reasons:

1. The study populations of most DLW studies are probably not representative of a European or Dutch adult population. The Committee notes that the data underlying the REE prediction equations of Henry and Schofield may not be fully representative of the European population, either. However, it expects that the data underlying the REE prediction equations is more representative than that of the TEE prediction equations since, in general, there is less variation in energy requirements due to any differences in body composition (within the limits of a healthy body weight) than in energy requirements due to differences in physical activity.[18,19]
2. The prediction equations for TEE are based on much less data than the prediction equations for REE. The prediction equations for TEE are thus less accurate. This argument still holds now that the IAEA dataset has recently become available.
3. The IAEA prediction equations for TEE do not include a 'physical activity' factor. Physical activity has a major influence on TEE, but with these equations it is not possible to take into account the level of physical activity (of the Dutch). Nor can an average energy requirement be determined for multiple PAL values.
4. IoM's prediction equation for TEE does include a 'physical activity' factor, but also the linear factor 'age'. The Committee questions whether it is logical to assume a linear relationship between age and TEE, especially since Henry and Schofield derived separate prediction equations for REE for three age groups (18-30, 30-60, 60+ y). Moreover, the IAEA publication shows that REE and TEE (after adjustment for fat mass and fat free mass) gradually decrease with age only after the age of 60 years.

The Committee agrees with EFSA's decision to use the prediction equations for REE developed by Henry (2005).[15] The first reason for this is that there were no major differences in the estimated REE between the various existing prediction equations. Based on Dutch reference figures for body weight and height, the Committee calculated that the differences in predicted REE based on the three equations used in the evaluated reports (Henry (2005),[15] Schofield (1985)[30] and Müller et al. (2004)[31]), within a sex and age group, are between 1 and 73 kcal/d (**Annex D** and **Figure 1**). The second reason is that all available prediction equations for estimating REE (see **Annex A** and **B**) have advantages and disadvantages, and that none of the equations seem to perform considerably better than the others when it comes to estimating the REE of the Dutch population.

EFSA's decision to derive ARs for four PAL values is adopted by the Committee, because the level of physical activity has a big impact on the total energy requirement and the level of physical activity varies greatly among different people. Deriving ARs for energy according to multiple PAL values better reflects the variation in (and range of) energy requirements within the population.

There is very little (DLW) data available that is suitable for determining the average PAL value and the distribution of PAL values for Dutch adults. The Committee believes that the data on which studies used by EFSA and the other organisations are based are likely not sufficiently representative for Dutch adults. The database compiled by Black (1996)[32] is considered outdated since the level of physical activity has likely changed in recent decades due to the digitalisation of the society, among other things. The two more recent US studies (2007-2008)[33-35] that were used by SACN are considered not representative for Dutch adults, because the study sample was not randomly selected and Americans likely have different activity habits than the Dutch. Something similar applies to the IAEA database:[42] 60% of the data comes from American subjects, whose activity habits are not considered to be representative of Dutch adults. The Committee is aware of two publications with DLW data collected from Dutch people: one included DLW measurements of 529 adults aged 18 to 99 years[44] and the other included DLW data of 26 older adults (mean age: 70 ± 5 y).[45] Those DLW data were collected 15 to 30 years ago. The Committee believes that the data probably do not adequately reflect today's activity pattern. In the absence of representative PAL values for Dutch adults, the Committee assessed to what extent the PAL values chosen by EFSA were in the range of PAL values observed in the available literature (Tables C1 and C2 in **Annex C**). The mean or median PAL values observed in those studies (1.6 to 1.75) are comparable to the two moderate PAL values chosen by EFSA (1.6 and 1.8). The lowest (1.4) and highest (2.0) PAL values chosen by EFSA are within the range of sustainable PAL values reported in the literature (1.0 to 2.5[32]), as well. In view of the above, and especially since recent PAL values of Dutch adults are lacking, the Committee decides to adopt the four PAL values proposed by EFSA.

The Committee replaces the highest age group used by EFSA (70-79 years) with 70 years and older, because reference values for body weight and height are available for Dutch adults aged 70 to 90 years (see 3.3 for more details).

#### 4.1.4 Summary

The Committee adopts EFSA's approach for deriving the average energy requirement for adults, but applies Dutch reference values for body weight and height, because Dutch people are on average taller and thus slightly heavier than other Europeans. Thus, the Committee determines the AR for adults by multiplying the predicted REE by a PAL value. REE is estimated by using the prediction equations of Henry (2005)[15] and ARs are determined for four PAL values (1.4, 1.6, 1.8 and 2.0). The final ARs for energy for adults from the Netherlands (rounded to the nearest 10 kcal) are shown in **Table 2**. The Committee notes that the changes in energy requirement with age occur gradually (and not abruptly). This might not be immediately clear from the numbers shown in the table, that tend to show abrupt declines in the AR between some age groups. This, however, is a consequence of the derivation method: ARs were derived by age group and not for each year of age separately. In particular for adults aged 18 up to and including 29 years, the Committee assumes that the AR of those with an age at the lower end of this age range is higher (and more in line with the AR of children aged 17 years; **Table 6**) than that of those with an age at the upper end. Some of the younger adults in this group are still growing (thus needing more energy), while others have already stopped growing before the age of 18 years. Something similar may apply to adults over 70 years of age. On average, the younger adults in this age range are expected to have a higher energy requirement than the older adults in this age range.


**Figure 1** Predicted REE in men and women, according to the prediction equations developed by Henry (2005),[15] Schofield (1985)[30] and Müller (2004)[31] and based on Dutch reference values for body weight and height

**Table 1** Overview of the criteria on which the average energy requirement for adults is based by EFSA and other national and international organisations

| Organisation | Age (y) | Method of derivation of AR | Method of estimation of BEE or REE (or TEE) | Method of derivation of PAL |
|---|---|---|---|---|
| EFSA, 2013[6] | 18-29,<br>30-39,<br>40-49,<br>50-59,<br>60-69,<br>70-79 | AR = predicted REE * PAL<br><br>ARs were provided according to sex and age category, and for four PAL values (without specifying a single most appropriate PAL value). | The average REE was estimated using the sex- and age-specific prediction equations developed by Henry (2005),[15,a] based on (reference) body weight and height. | DLW studies (e.g.[32]) were used to determine PAL values for different levels of physical activity. Four PAL values with equal intervals were defined within the observed range of physical activity levels associated with a sustainable lifestyle, and those values were used for calculating the ARs: 1.4, 1.6, 1.8 and 2.0. |
| HCNL, 2001[7] | 19-30,<br>31-50,<br>51-70,<br>>70 | AR = predicted REE * PAL<br><br>ARs were provided according to sex and age category (and for a single PAL value). | The average REE was estimated using the sex- and age-specific prediction equations developed by Schofield et al. (1985),[30] based on (reference) body weight. | DLW studies in free-living subjects from affluent societies were used to determine age-specific PAL values for different levels of physical activity.[32] Age-specific "ideal" PAL values and "low average" PAL values were defined, and the latter were used for calculating ARs: 19-50 y: 1.7; 51-70 y: 1.6; and >70 y: 1.5. |
| FAO/WHO/UNU, 2004[8] | 18-29.9,<br>30-59.9,<br>≥60 | AR = predicted REE * PAL<br><br>ARs were provided according to sex and age category, and for multiple body weights and PAL values (without specifying a single most appropriate PAL value). | The average REE was estimated using the sex- and age-specific prediction equations developed by Schofield et al. (1985),[30] based on (reference) body weight. | DLW studies in free-living subjects from affluent societies were used to determine three lifestyle categories with corresponding (ranges of) PAL values that can be sustained for a long period of time (1.4-2.4):[32] sedentary or light active: 1.40-1.69, active or moderately active: 1.70-1.99; and vigorous or vigorously active: 2.00-2.40. The midpoint PAL value of the category corresponding to the population of interest is recommended for calculation of the AR. PAL values used for sample calculations: 1.45, 1.60, 1.75, 1.90, 2.05 and 2.20. |
| IoM, 2005[9] | ≥19 | AR = predicted TEE<br><br>ARs were provided for men and women aged 30 y, according to height, BMI and PAL value (without specifying a single most appropriate PAL value). For each year of age below or above 30, it was recommended to add or subtract, respectively, 7 kcal/d for women and 10 kcal/d for men. | IoM estimated TEE instead of REE. A normative IoM database of DLW studies was used to derive sex-specific prediction equations for TEE, based on age, (reference) body weight, height and a PAL value.[9,b] | DLW studies in 407 adults with healthy BMIs (18.5-25 kg/m$^2$) and sustainable PAL values (1.0-2.5), assembled by IoM, were used to determine (ranges of) PAL values for four different levels of physical activity:[9] sedentary: ≥1.0 to <1.4; low active: ≥1.4 to <1.6; active: ≥1.6 to <1.9; and very active: ≥1.9 to <2.5. A physical activity coefficient (corresponding to one of the four PAL values) was included in the prediction equation for TEE. |

| | | | | |
|---|---|---|---|---|
| NCM, 2014[10] | 18-30,<br>31-60,<br>61-74 | AR = predicted REE * PAL<br><br>ARs were provided according to sex and age category, and for three values of PAL (without specifying a single most appropriate PAL value). | The average REE was estimated using the sex- and age-specific prediction equations developed by Henry (2005),[15] based on (reference) body weights and height. | DLW studies were used to determine PAL values for different levels of physical activity.[32,33,35] Three PAL values with equal intervals were defined, and those values were used for calculating the ARs: 1.4, 1.6 and 1.8. A PAL value of 1.6 was assumed to be the average PAL for adults in Nordic countries (no explanation was provided except that a PAL value of 1.6 is compatible with sedentary work and some physical activity). |
| DACH, 2015[11,12] | 19 to <25,<br>25 to <51,<br>51 to <65,<br>≥65 | AR = predicted REE * PAL<br><br>ARs were provided according to sex and age category, and for three values of PAL (without specifying a single most appropriate PAL value). | The average REE was estimated using the prediction equations developed by Müller et al. (2004),[31] based on (reference) body weight, age and sex. | DACH used four PAL values with equal intervals to calculate ARs: 1.4, 1.6, 1.8 and 2.0. These values were most likely obtained from EFSA. |
| SACN, 2011[13] | 19 to <25,<br>25 to <35,<br>35 to <45,<br>45 to <55,<br>55 to <65,<br>65 to <75,<br>≥75 | AR = predicted REE * PAL<br><br>ARs were provided according to sex and age category, and for three levels of PAL. The median PAL value of 1.63 was assumed to be the population average. | Average REE was estimated using the sex- and age-specific prediction equations developed by Henry (2005),[15] based on (reference) body weight and height. | Two DLW studies in free-living individuals were used to determine PAL values for three different levels of physical activity.[33-35,c] The 25$^{th}$ (PAL 1.49), 50$^{th}$ (PAL 1.63) and 75$^{th}$ (PAL 1.78) percentile of the distribution of PAL values observed in the combined datasets were considered low, average and high levels of physical activity, respectively, and those values were used for calculating the ARs. |

AR: average requirement; BEE: basal energy expenditure; d: day; DACH: German-speaking countries Germany (Deutschland), Austria and Switzerland (Confoederatio Helvetica); DLW: doubly-labelled water; EFSA: European Food Safety Authority; FAO/WHO/UNU: Food and Agriculture Organisation of the United Nations/World Health Organisation/United Nations University; g: grams; HCNL: Health Council of the Netherlands; IoM: Institute of Medicine; NCM: Nordic Council of Ministers; PAL: physical activity level; REE: resting energy expenditure; SACN: Scientific Advisory Committee on Nutrition; TEE: total energy expenditure; y: years

[a] The prediction equations developed by Henry have overlapping age bands (18-30, 30-60 and ≥60 y).[15] EFSA used the prediction equations for 18-30-year-olds for adults aged 18-29 y, the equations for the 30-60-year-olds for those aged 30-39, 40-49 and 50-59 y, and the equations for the ≥60-year-olds for those aged 60-69 and 70-79 y.

[b] IoM compiled a dataset of DLW studies that were mostly conducted in Western countries (n=407 mostly Caucasian adults). IoM noted the following: “the available DLW data are not from randomly selected individuals and do not constitute a sample representative of the population of the United States and Canada. However, the measurements were obtained in men, women, and children whose ages, body weights, heights, and physical activities varied over wide ranges. At the present time, a few age groups are underrepresented and interpolations had to be performed in these cases. Thus, while the available DLW data do not yet provide an entirely satisfactory set of data, they nevertheless offer the best currently available information.”

[c] The OPEN and Beltsville datasets, comprised of US subjects whose TEE was measured with the DLW method and whose BEE was measured (in the Beltsville study) or predicted (in the OPEN study, using the Henry equations), were used to derive PAL values.

**Table 2** Average energy requirements and their components for adults (18 years and older) from the Netherlands[a,b]

| Sex | Age (y) | Dutch reference weight (kg) | Dutch reference height (cm) | Predicted REE (kcal/d)[c] | AR (kcal/d)[a] at PAL=1.4 | AR (kcal/d)[a] at PAL=1.6 | AR (kcal/d)[a] at PAL=1.8 | AR (kcal/d)[a] at PAL=2.0 |
|---|---|---|---|---|---|---|---|---|
| Men | 18 up to and including 29 | 75.6 | 185.0 | 1781 | 2490 (2493) | 2850 (2849) | 3210 (3205) | 3560 (3561) |
| Men | 30 up to and including 39 | 73.1 | 182.3 | 1683 | 2360 (2356) | 2690 (2692) | 3030 (3029) | 3370 (3365) |
| Men | 40 up to and including 49 | 73.8 | 183.2 | 1695 | 2370 (2374) | 2710 (2713) | 3050 (3052) | 3390 (3391) |
| Men | 50 up to and including 59 | 75.4 | 181.1 | 1702 | 2380 (2383) | 2720 (2724) | 3060 (3064) | 3410 (3405) |
| Men | 60 up to and including 69 | 72.7 | 177.8 | 1535 | 2150 (2149) | 2460 (2455) | 2760 (2762) | 3070 (3069) |
| Men | 70 and older | 73.6 | 175.1 | 1530 | 2140 (2142) | 2450 (2449) | 2760 (2755) | 3060 (3061) |
| Women | 18 up to and including 29 | 64.6 | 171.0 | 1441 | 2020 (2018) | 2310 (2306) | 2600 (2595) | 2880 (2883) |
| Women | 30 up to and including 39 | 63.1 | 169.3 | 1354 | 1900 (1896) | 2170 (2167) | 2440 (2438) | 2710 (2709) |
| Women | 40 up to and including 49 | 62.8 | 169.0 | 1350 | 1890 (1891) | 2160 (2161) | 2430 (2431) | 2700 (2701) |
| Women | 50 up to and including 59 | 63.8 | 166.5 | 1346 | 1890 (1885) | 2150 (2154) | 2420 (2423) | 2690 (2692) |
| Women | 60 up to and including 69 | 62.9 | 165.4 | 1243 | 1740 (1740) | 1990 (1989) | 2240 (2237) | 2490 (2486) |
| Women | 70 and older | 63.2 | 162.2 | 1232 | 1730 (1725) | 1970 (1971) | 2220 (2218) | 2460 (2464) |

AR: average requirement; BW: body weight; cm: centimetres; g: grams; kcal/d: kilocalories per day; kg: kilograms; REE: resting energy expenditure; y: years

[a] ARs are rounded to the nearest 10 kcal. Values as calculated, before rounding, are indicated between brackets.

[b] AR = predicted REE * PAL.

[c] REE was estimated using the sex- and age-specific prediction equations developed by Henry (2005), based on body weight and height.[15] Like EFSA, the Committee uses the prediction equations for 18-30 year-olds for adults aged 18-29 y, the equations for the 30-60 year-olds for those aged 30-39, 40-49 and 50-59, and the equations for the ≥60 year-olds for those aged 60-69 and ≥70 y.

## 4.2 Infants (0 up to and including 11 months)

**Table 3** provides an overview of the criteria on which EFSA and the other organisations have based their ARs for energy for infants.

### 4.2.1 EFSA's approach and considerations and comparison with other organisations

EFSA did not derive an AR for infants aged 0 through 6 months, because it assumed that an infant's energy requirement is equal to the energy supply from human milk. It did only derive ARs for infants from 7 through 11 months of age. All other organisations derived ARs for infants from birth up to and including 11 months (and IoM up to and including 35 months).

*General approach*

EFSA and the other organisations determined the AR for infants as the sum of predicted TEE and the energy deposited in growing tissues. During growth, energy is stored as protein and fat in newly formed tissues (known as 'energy deposition') and energy is expended for synthesis of these new tissues (also called 'synthetic cost'). A TEE measured using the DLW method includes the synthetic cost, but not the energy deposited in growing tissues. Therefore, the energy deposited in growing tissues should be added to the TEE to calculate the AR.

*Total energy expenditure*

All of the organisations, except for HCNL in 2001, used a prediction equation to estimate TEE based on reference body weights for infants. Note that different reference values for body weight were applied. In addition, the reports differ as to whether one AR was set for all infants or ARs were set according to the feeding mode:

- Almost all organisations used one or more of the prediction equations developed by Butte (2005)[46] to predict TEE. Those equations were based on a longitudinal study by Butte (2000)[47] in which DLW measurements of TEE were performed at 3 to 6 month intervals for the first two years of life in 76 healthy, full-term infants with adequate body weight who were initially breast-fed (n=40) or formula-fed (n=36) for 4 months. Butte et al. derived prediction equations for all infants and for two subgroups of infants (breast-fed infants and formula-fed infants). The reason for this is that TEE was observed to be lower (12% at 3 months to 3% at 12 months) in exclusively breast-fed infants than in formula-fed infants in the first year of life.[47-50] The prediction equation for all infants was derived from the data on breast-fed and formula-fed infants and is meant to be applied to infants who are both breast- and formula-fed ("mixed-fed") or whose mode of feeding is unknown. This work was done as a preparation for the FAO/WHO/UNU report (2004).[8]
    - EFSA and DACH set one AR for all infants (no separate ARs were derived according to feeding mode), for which it used the prediction equation for breast-fed infants. EFSA's motivation was that the data on formula-fed infants was no longer appropriate, since the composition of infant formula had

significantly changed in recent years. Therefore, it deemed the equation based on infants who were initially breast-fed to be suitable for the calculation of TEE of all infants.
    - NCM also set a single AR for all infants, due to the fact that the differences in energy expenditure between the feeding groups were small (NCM reported a maximum difference of 20 kJ/kg). It did not describe which of Butte's prediction equations it used to estimate TEE.
    - FAO/WHO/UNU and SACN derived separate ARs for breast-fed infants, formula-fed infants and for infants who are mixed-fed or whose mode of feeding is unknown, based on the respective prediction equations developed by Butte.
- IoM did not use the prediction equations developed by Butte et al., but had its own prediction equations derived from its own dataset of DLW studies in infants aged 36 months and under who were within the 3rd and 97th percentile of US body weight-for-height values. Considering the very similar prediction equations for TEE (in kcal/d) derived by Butte et al. (*TEE = 88.6*BW – 99.4*; Table A8 in **Annex A**) and by IoM (*TEE = 89*BW – 100*; Table A9), the fact that both reported that they included 320 data points (with a maximum of 6 repeated measurements per individual) and that the maximum age in the IoM dataset was 2.11 years, the Committee assumes that IoM's[9] underlying dataset is very similar to Butte's.[47]

HCNL did not use a prediction equation to estimate TEE in 2001, but obtained TEE values from data from only two DLW studies, including the original study by Butte et al. (2000).[47]

*Energy deposited in growing tissues*

All organisations including EFSA calculated the energy deposited in growing tissues on the basis of reference values for the amount of energy deposited in growing tissues per gram of body weight gain (in kJ/g) and reference body weight gains. In addition, all organisations except for HCNL in 2001 retrieved the reference values for the amount of energy deposited from the publication of Butte et al. (2000).[51] Butte et al. estimated average 3-month gains in protein and fat (g/d) based on changes in body composition of healthy and normally-growing term infants.[51] Based on the energy density of deposited protein (5.65 kcal/g) and fat (9.25 kcal/g) and the average gain in body weight (g/d) in those infants, the average amount of energy deposited per gram of body weight gain was calculated. Those values were then applied to reference body weight gains used by the respective organisations. The latter resulted in (slightly) different absolute values for energy deposition. In the HCNL report, an older body composition model was used that was different to the one used by Butte et al. This model was considered outdated and was therefore not considered in the Committee's evaluation.

To conclude, due to different prediction equations used to derive TEE values and the different reference body weights and body weight gains applied, the specific AR values differed among the various organisations.

#### 4.2.2 The Committee's conclusions for the Netherlands

The Committee agrees with EFSA's decision not to derive an AR for infants aged up to and including 5 months of age (first half of infancy). Breast milk is considered the optimal food for this youngest group.[52] When infants are fed according to their needs – so called 'ad libitum' feeding is advised for infants[52] – the energy requirement is assumed to be equal to the energy content of breast milk. Therefore, the Committee believes that an AR for breast-fed infants has no (practical) value. The Committee also sees no reason to derive an AR for infants in this age group that are formula-fed. The composition of infant formula, and thus its energy density, is based on the average composition of breast milk and is regulated by the European Commission (based on an EFSA report[52] and the international standard from the Codex Alimentarius[53]). Assuming that formula-fed infants are also fed ad libitum, their energy intake from infant formula should meet their energy requirement. Unlike EFSA, the Committee believes that an AR should also be derived for infants aged 6 months, since complementary feeding contributes (significantly) to the infant's total energy intake from that age (see Section 3.3).

The Committee agrees with EFSA's motivation regarding the derivation of the AR for infants aged 7 up to and including 11 months. Therefore, it adopts EFSA's approach, but applies Dutch reference values for weight and weight gain. Using this same approach, the Committee also derives an AR for infants aged 6 months.

#### 4.2.3 Summary

The Committee does not derive an AR for infants up to and including 5 months of age (first half of infancy). For infants aged 6 up to and including 11 months (second half of infancy), the Committee calculates the AR as the sum of the predicted TEE and the energy deposited in growing tissues. It uses Butte's prediction equation for breast-fed infants[46,47] to predict the TEE for all infants (regardless of the mode of feeding), on the basis of Dutch reference weights. To estimate the energy deposited in growing tissues, the Committee uses the reference values for the amount of energy deposited in growing tissues per gram of body weight gain (in kJ/g) derived by Butte et al. (2000)[51] and applies Dutch reference values for body weight gain. **Table 4** provides an overview of the ARs for energy (rounded to the nearest 10 kcal) and their components for infants from the Netherlands.

**Table 3** Overview of the criteria on which the average energy requirements for infants are based by EFSA and other national and international organisations

| Organisation | Age (mo) | Method of derivation of AR | Method of derivation of TEE | Method of derivation of energy deposited in growing tissues |
|---|---|---|---|---|
| EFSA, 2013[6] | 0 to ≤6 | NA<br>AR = energy supply from human milk | NA/NR | NA/NR |
| | 7 to ≤11 | AR = predicted TEE + energy deposited in growing tissues[a]<br><br>ARs were provided according to sex and age (one-month intervals). | The average TEE was estimated using a prediction equation, based on body weight, that was derived from DLW data. The prediction equation developed by Butte (2005)[46] for breast-fed infants was used, and assumed to be valid for all infants (regardless of the mode of feeding).[b] | The estimated amount of energy deposited as proteins and fat in newly-formed tissue (in kJ per gram of body weight gained) was calculated from average protein and fat gains (using a multi-component body composition model) in healthy, normally-growing, term infants[51] and the energy contents of protein and fat.[c] The retrieved values were applied to (reference) body weight gains. |
| HCNL, 2001[7] | 0 to ≤2,<br>3 to ≤5,<br>6 to ≤11 | AR = estimated TEE + energy deposited in growing tissues[a]<br><br>ARs were provided according to age group. | The average TEE was not estimated using a prediction equation, but rather on the basis of average TEE values observed in two DLW studies.[51,54] | The estimated amount of energy deposited as proteins and fat in newly-formed tissue (in kJ per gram of body weight gained) was calculated from estimated protein and fat gains (using a multi-component body composition model in a term infant[55]; an older model compared to the one used by the other organisations) and the energy contents of protein and fat.[c] The retrieved values were applied to (reference) body weight gains. |
| FAO/WHO/UNU, 2004[8] | 1 to 12 | AR = predicted TEE + energy deposited in growing tissues[a]<br><br>ARs were provided according to age (one-month intervals), sex (boys, girls or both) and mode of feeding (breast-fed, formula-fed or mixed-fed). | The average TEE was estimated using prediction equations, based on body weight, that were derived from DLW data. The prediction equations developed by Butte (2005)[46] for breast-fed infants, formula-fed infants and mixed-fed infants were used.[b] | The estimated amount of energy deposited as proteins and fat in newly-formed tissue (in kJ per gram of body weight gained) was calculated from average protein and fat gains (using a multi-component body composition model) in healthy, normally-growing, term infants[51] and the energy contents of protein and fat.[c] The retrieved values were applied to (reference) body weight gains. |
| IoM, 2005[9] | 0 to <36 | AR = predicted TEE + energy deposited in growing tissues[a]<br><br>ARs were provided according to sex and age (one-month intervals up to 1 y, 3-month intervals thereafter). | The average TEE was estimated using a prediction equation, based on body weight, that was derived from DLW data. IoM derived a prediction equation itself based on its own dataset from DLW studies in healthy infants and children aged 35 mo and under.[9,d] | The estimated amount of energy deposited as proteins and fat in newly formed tissue (in kJ per gram of body weight gained) was calculated from average protein and fat gains (using a multi-component body composition model) in healthy, normally-growing, term infants[51] and the energy contents of protein and fat.[c] The retrieved values were applied to (reference) body weight gains. |

| | | | | |
|---|---|---|---|---|
| NCM, 2014[10] | 1, 3, 6, 12 | AR = predicted TEE + energy deposited in for growth[a]<br><br>ARs were provided according to sex and age category, assuming a mixture of breastfeeding and complementary foods. | The average TEE was estimated using prediction equations, based on body weight, that were derived from DLW data. One or more of the prediction equations developed by Butte (2005)[46] were used, but it is not reported which one(s).[b] The estimated ARs are assumed to be valid for all infants (regardless of the mode of feeding). | The estimated amount of energy deposited as proteins and fat in newly formed tissue (in kJ per gram of body weight gained) was calculated from average protein and fat gains (using a multi-component body composition model) in healthy, normally-growing, term infants[51] and the energy contents of protein and fat.[c] The retrieved values were applied to (reference) body weight gains. |
| DACH, 2015[11,12] | 0 to <4,<br>4 to <12 | AR = predicted TEE + energy deposited in growing tissues[a]<br><br>ARs were provided according to sex and age category. | The average TEE was estimated using a prediction equation, based on body weight, that was derived from DLW data. The prediction equation developed by Butte (2005)[46] for breast-fed infants was used for all infants (regardless of the mode of feeding).[b] | The estimated amount of energy deposited as proteins and fat in newly formed tissue (in kJ per gram of body weight gained) was calculated from average protein and fat gains (using a multi-component body composition model) in healthy, normally-growing, term infants[51] and the energy contents of protein and fat.[c] The retrieved values were applied to (reference) body weight gains. |
| SACN, 2011[13] | 1 to ≤12 | AR = predicted TEE + energy deposited in growing tissues[a]<br><br>ARs were provided according to sex, age (one-month intervals) and mode of feeding (breast-fed, formula-fed or mixed-fed/unknown). | The average TEE was estimated using prediction equations, based on body weight, that were derived from DLW data. The prediction equations developed by Butte (2005)[46] for breast-fed infants, formula-fed infants and mixed-fed infants were used (according to FAO/WHO/UNU 2004). [b] | The estimated amount of energy deposited as proteins and fat in newly formed tissue (in kJ per gram of body weight gained) was calculated from average protein and fat gains (using a multi-component body composition model) in healthy, normally-growing, term infants[51] and the energy contents of protein and fat.[c] The retrieved values were applied to (reference) body weight gains. |

AR: average requirement; BEE: basal energy expenditure; DACH: German-speaking countries Germany (Deutschland), Austria and Switzerland (Confoederatio Helvetica); DLW: doubly-labelled water; EFSA: European Food Safety Authority; FAO/WHO/UNU: Food and Agriculture Organisation of the United Nations/World Health Organisation/United Nations University; HCNL: Health Council of the Netherlands; IoM: Institute of Medicine; kJ: kilojoules; mo: months; NCM: Nordic Council of Ministers; SACN: Scientific Advisory Committee on Nutrition; TEE: total energy expenditure

[a] During growth, energy is stored as protein and fat in newly-formed tissues (known as 'energy deposition') and energy is expended in the synthesis of these new tissues (also called 'synthetic cost'). TEE measured using the DLW method includes the synthetic cost, but not the energy deposited in growing tissues.

[b] The prediction equations developed by Butte (2005) for breast-fed infants and formula-fed infants were derived from DLW data on healthy, normally-growing full-term infants with adequate body mass that were initially breast-fed (n=40) or formula-fed (n=36) for 4 months after birth. The prediction equation for mixed-fed infants was based on both breast-fed and formula-fed infants (n=76).[46]

[c] Energy values of 23.6 kJ (5.65 kcal) per gram of deposited protein and 38.7 kJ (9.25 kcal) per gram of deposited fat were used for the calculation.

[d] IoM compiled its own DLW dataset, comprising of infants and children aged 36 months and under within the 3rd to 97th percentile of body weight-for-height (n=320).[9]

**Table 4** Average energy requirements and their components for infants aged 6 up to and including 11 months from the Netherlands[a,b]

| Sex | Age (mo) | Dutch reference weight (kg) | Predicted TEE (kcal/d)[c] | Protein gain from reference model (g/d)[d] | Fat mass gain from reference model (g/d)[d] | Weight gain from reference model (g/d)[d] | Energy deposition per gram of weight gain (kcal/g)[e] | Dutch reference value for weight gain (g/d) | Energy deposited in growing tissues (kcal/d)[f] | AR (kcal/d)[a] |
|---|---|---|---|---|---|---|---|---|---|---|
| Boys | 6 | 7.6 | 553 | 2.3 | 0.5 | 11.8 | 1.5 | 16.4 | 24 | 580 (578) |
| Boys | 7 | 8.1 | 600 | 2.3 | 0.5 | 11.8 | 1.5 | 14.7 | 22 | 620 (622) |
| Boys | 8 | 8.6 | 646 | 2.3 | 0.5 | 11.8 | 1.5 | 13.8 | 21 | 670 (667) |
| Boys | 9 | 9.0 | 683 | 1.6 | 1.7 | 9.1 | 2.7 | 12.1 | 33 | 720 (716) |
| Boys | 10 | 9.4 | 720 | 1.6 | 1.7 | 9.1 | 2.7 | 11.8 | 32 | 750 (752) |
| Boys | 11 | 9.9 | 767 | 1.6 | 1.7 | 9.1 | 2.7 | 10.7 | 29 | 800 (796) |
| Girls | 6 | 7.2 | 516 | 2.0 | 0.8 | 10.6 | 1.8 | 15.8 | 28 | 540 (544) |
| Girls | 7 | 7.7 | 563 | 2.0 | 0.8 | 10.6 | 1.8 | 14.0 | 25 | 590 (587) |
| Girls | 8 | 8.1 | 600 | 2.0 | 0.8 | 10.6 | 1.8 | 12.0 | 21 | 620 (621) |
| Girls | 9 | 8.5 | 637 | 1.8 | 1.1 | 8.7 | 2.3 | 11.2 | 26 | 660 (663) |
| Girls | 10 | 8.8 | 665 | 1.8 | 1.1 | 8.7 | 2.3 | 11.0 | 26 | 690 (690) |
| Girls | 11 | 9.2 | 702 | 1.8 | 1.1 | 8.7 | 2.3 | 9.9 | 23 | 730 (725) |

AR: average requirement; g/d: grams per day; kcal/d: kilocalories per day; kg: kilograms; mo: months; TEE: total energy expenditure

[a] ARs are rounded to the nearest 10 kcal. Values as calculated, before rounding, are indicated between brackets.

[b] AR = TEE + energy deposition in growing tissues

[c] TEE was estimated with the prediction equation for breast-fed infants developed by Butte et al. (2005).[46]

[d] Values obtained from Butte et al. (2000).[51]

[e] Energy deposition per gram of weight gain = ((protein gain * 5.65) + (fat gain * 9.25)) / weight gain from reference model.[51] Energy values of 5.65 kcal per gram of deposited protein and 9.25 kcal per gram of deposited fat were used.

[f] Energy deposition in growing tissues = energy deposition per gram of weight gain

* Dutch reference value for weight gain.

## 4.3 Children (1 year up to and including 17 years)

**Table 5** provides an overview of the criteria on which EFSA and the other organisations have based their ARs for energy for children.

### 4.3.1 EFSA's approach and comparison with other organisations

*General approach*

EFSA determined the AR for children by multiplying the predicted REE by a PAL value, and applying a multiplication factor to account for the energy required for growth. It used the prediction equations for REE developed by Henry (2005).[15] EFSA derived one AR for the age group of 1-3 years, by using a PAL value of 1.4. For children aged 4 years and older, EFSA derived three ARs, according to different levels of physical activity: PAL values of 1.4, 1.6 and 1.8 were used for the age group of 4-9 years and 1.6, 1.8 and 2.0 for the age group of 10-17 years. As with adults, these PAL values were chosen because they are within the range of PAL values observed in DLW studies in free-living children and are consistent with a sustainable lifestyle. For the energy requirement for growth, EFSA followed the assessment of FAO/WHO/UNU (2004) that throughout childhood the average energy costs of growth are approximately equal to a 1% increase in PAL. This was accounted for by applying a multiplication factor for growth of 1.01. It should be noted that the rate of growth varies during childhood. The age of onset of the adolescent growth spurt varies substantially among children. This means that, although the multiplication factor is constant at group level, the energy costs of growth in an individual child will increase more substantially during the adolescent growth spurt. Yet, the energy deposited for growth after the first year of life is on average relatively small (<2% of TEE, and 4% of TEE during the adolescent growth spurt, on average).[6,9,56]

HCNL in 2001, NCM (2014), DACH (2015) and SACN (2011) took the same approach as EFSA for deriving the ARs for children: as the product of the predicted REE, a PAL value and a multiplication factor for growth. FAO/WHO/UNU (2004) and IoM (2005) used another approach for estimating the AR, by which TEE was estimated through the use of prediction equations. FAO/WHO/UNU derived sex-specific prediction equations for TEE, as a function of body weight, using data of 1609 children aged 1-18 years in whom TEE was measured using the DLW method or heart rate monitoring technique.[57,58] IoM derived sex-specific prediction equations for TEE, as a function of age, body weight, height and physical activity, from its own dataset from DLW studies in 525 US children aged 3-18 years.[9] **Annex A** shows the prediction equations used in those reports.

*Prediction equations to estimate REE*
For the prediction of REE, NCM, DACH and SACN, like EFSA, used the equations developed by Henry (2005).[15] HCNL used the Schofield (1985) equations in 2001.[30]

*PAL values used to estimate the AR*
Similar to adults, all organisations used DLW data (in combination with heart rate monitoring data collected by FAO/WHO/UNU) to directly or indirectly derive PAL values for children. However, the methods and datasets used to derive the PAL values differed among organisations, as was the case for the data relating to adults (see Section 4.1.1):

- EFSA and DACH applied PAL values with equal intervals within the range of sustainable PAL values observed in DLW studies. EFSA therefore considered the SACN children's dataset (a dataset compiled by SACN).[13]
- SACN determined PAL values based on the 25th, 50th and 75th percentile of the observed distribution of PAL values in its SACN children's dataset,[13] which was comparable to its approach for adults. NCM adopted the approach of SACN.
- In 2001, HCNL considered (only) the mean of observed PAL values in a children's dataset.[59]
- FAO/WHO/UNU considered the mean PAL value, which was calculated from predicted TEE and BEE using its review of DLW and heart rate monitoring studies,[58] to be the moderate physical activity level. For children performing light and heavy physical activity, energy requirements (or PAL values) were defined by subtracting or adding, respectively, 15% from the "average" energy requirement (or "moderate" PAL value).
- IoM determined four categories of physical activity and accompanying ranges of PAL values (equal to adults), and included a coefficient corresponding to each physical activity category in the prediction equation for TEE.

The specific PAL values resulting from these approaches (and underlying datasets) are shown in **Table 5** and included in a graph in **Figure 2**. This graph shows that most organisations believe that PAL values increase with age during childhood. EFSA, SACN and NCM used different PAL values for three age groups in childhood. DACH specified multiple PAL values per age group. FAO/WHO/UNU used multiple PAL values for each year of age and made a distinction between boys and girls.

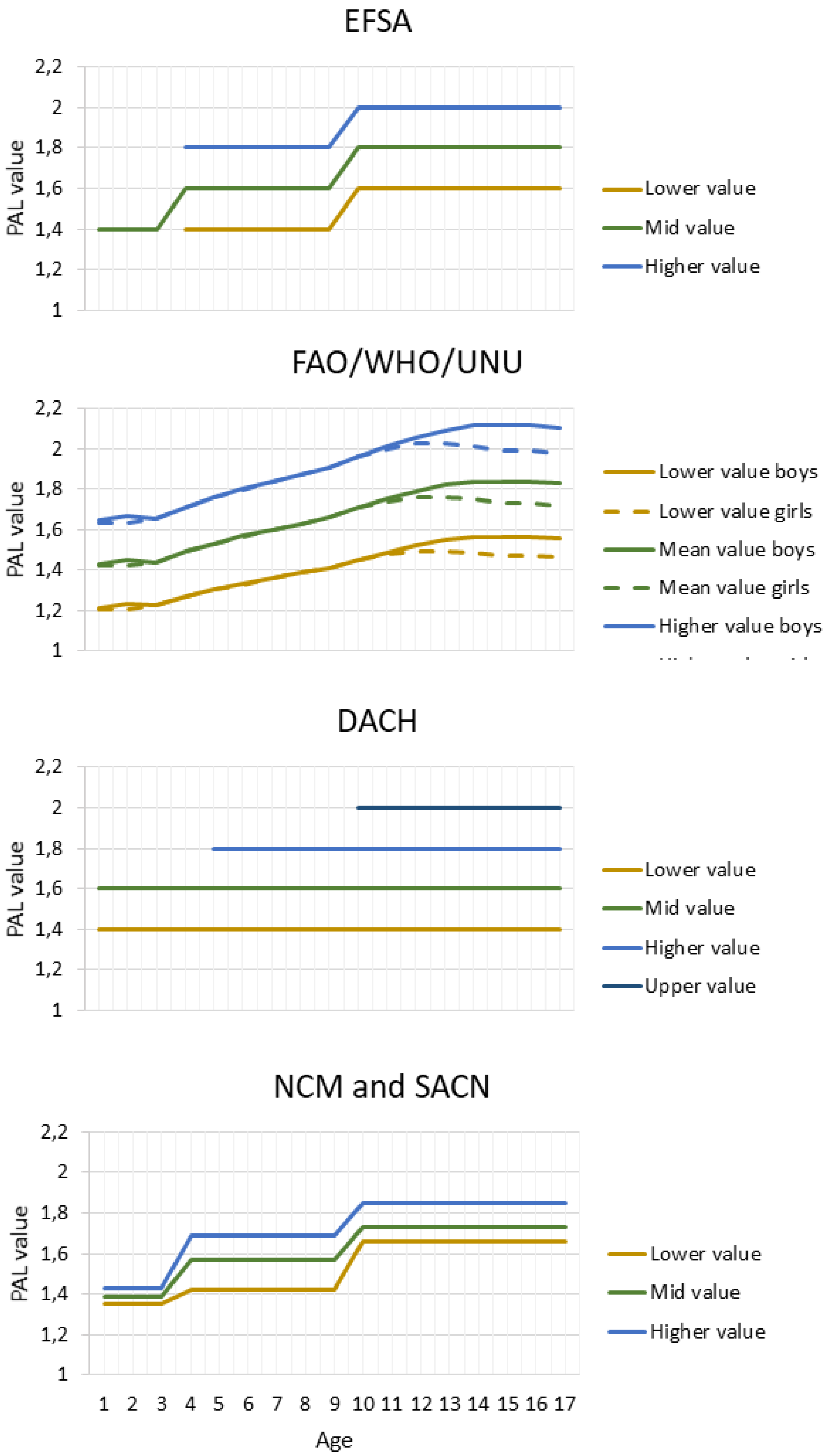


**Figure 2** PAL values used by the different organisations for children of various ages

*Energy requirement for growth*

To account for the energy requirement for growth, the organisations used either a multiplication factor or an additive factor. EFSA, DACH and SACN applied a multiplication factor for growth of 1.01, which is assumed to be equal to the average daily amount of energy deposited in growing tissues of 2 kcal per gram of weight gain throughout childhood.[8] This value for energy deposition was calculated by FAO/WHO/UNU by multiplying bodily percentages of protein (20%) and fat (10%) by the energy content of protein (5.65 kcal/g) and fat (9.25 kcal/g).[46,47] FAO/WHO/UNU also calculated that this 2 kcal/g weight gain was similar to a 1% higher PAL value, and can be accounted for by using a multiplication factor of 1.01. However, it used an additive factor itself. This means that it added the energy expenditure for growth (2 kcal/g * mean daily body weight gain) to the predicted TEE. HCNL (in 2001) and IoM used a comparable additive factor. NCM did not take the energy requirement for growth into account (nor did it explain why).

### 4.3.2 EFSA's considerations

EFSA rejected the approach used by FAO/WHO/UNU and IoM for estimating TEE directly from DLW studies for the same reasons as in the case of adults (Section 4.1.2). The main argument was that the available DLW data are likely not representative of the European population, in part because the study populations might not represent the distribution of physical activity levels in European children. Thus, EFSA calculated TEE as the product of predicted REE and PAL values (based on DLW data).

EFSA found two prediction equations suitable for estimating REE in children, because these equations were derived from large datasets of children in the age range of 0 to 18 years.[15,30] The difference in predicted REE (means) based on these two equations, within a sex and age group, was very small (at most 62 kcal/d). EFSA decided to derive REE for children on the basis of the equations developed by Henry (2005) for the same reason as for adults (due to the larger underlying database).[15]

EFSA did not derive PAL values for children by dividing TEE (based on DLW data) by REE (measured or predicted), for the same reasons as for adults (Section 4.1.2). It used PAL values with equal 0.2-point intervals within the range of sustainable physical activity levels that were observed in DLW studies in children (i.e. SACN's children dataset). This resulted in one to three ARs for energy per age group.

According to FAO/WHO/UNU, the average amount of energy deposited in growing tissues was approximately 2 kcal per gram of body weight gained (and equal to a 1% higher PAL value). EFSA stated that even if this value had been under- or overestimated by 50%, that it would generate only a very small error in calculated energy requirements (±1%). Therefore, EFSA deemed it reasonable to use the more easily applicable multiplication factor for growth of 1%.

### 4.3.3 The Committee's conclusions for the Netherlands

As regards data from adults, the Committee considers the publication of the IAEA that includes DLW data of various age groups (see Section 4.1.3), in addition to the other seven reports, to determine its approach for deriving the average energy requirement for children.[42,43]

The Committee decides to use prediction equations for REE and not to use prediction equations for TEE (from IoM or the IAEE), for the following reasons:

1. The study populations in most DLW studies are probably not representative of European (or Dutch) children. The IoM DLW dataset only included participants from the USA, who were also not randomly selected. The dataset used by FAO/WHO/UNU mainly involved participants from the USA or the UK (62% from US or UK, 18% from Canada, Denmark, Sweden or the Netherlands). This dataset also partly (30%) included TEE data determined by means of heart rate monitoring instead of the DLW method, and is therefore less reliable.[60] The IAEA dataset consisted for the most part of participants from the USA (approximately 61%), as well.
2. The prediction equations for TEE are based on much less data than the prediction equations for REE. The prediction equations for TEE are thus less accurate. The recent IAEA dataset includes considerably more TEE data than the IoM dataset, but not much more than the FAO/WHO/UNU dataset. However, the extra data are mainly from the USA (see argument 1).

The Committee agrees with EFSA's decision to use the prediction equations developed by Henry (2005) to estimate REE.[15] The reasons are similar to those provided in relation to adults (Section 4.1.3). In short, there are no major differences in estimated REE between the prediction equations developed by Henry (2005)[15] and Schofield (1985)[30] when applying Dutch reference figures: the differences in predicted REE (means) within a sex and age group are between 2 and 56 kcal/d (Table D2 in **Annex D** and **Figure 3**). REE predicted using the Henry equations yielded slightly higher values than REE predicted using the Schofield equations for children aged 1 up to and including 9 years, whereas the opposite was true for children aged 10 up to and including 17 years. Furthermore, both available prediction equations for estimating REE (see **Annex A** and **B**) have advantages and disadvantages, and neither of the equations seems to perform considerably better for estimating REE.

The prediction equations that Henry defined for three age groups of children have overlapping age bands: 0-3 years, 3-10 years and 10-18 years. EFSA, DACH and SACN used the prediction equations for 3-10-year-olds for children aged 3 years and the equation for the 10-18-year-olds for children aged 10 years. The Committee uses the same approach for children aged 3 years, assuming that 0-3 years means 0 up to (but not including) 3 years (or 0 up to and including 2 years). For children aged 10 years, the Committee notes that applying the equation for 10-18-year-olds resulted in an (physiologically) illogical value as compared to the adjacent ages. The difference in predicted REE between the 9- and the 10-year-olds was only 4 kcal among boys and 23 kcal among girls, whereas the differences between the 8- and the 9-year-olds and between the 10- and the 11-year-olds were much greater (65 kcal and 67 kcal among boys and 64 kcal and 57 kcal among girls, respectively). Therefore, the Committee estimates the REE for the ages of 9 years (highest age of the lower age category) and 10 years (lowest age of the higher age category) each using the equation for 3-10-year-olds and the equation for 10-18-year-olds, and considers the average of the two to be the best approximation of REE.

For each year of age, the Committee uses the reference weight at the lower boundary of that age to predict REE. For example, for children aged 2 years, the Committee uses the reference weight of children aged 2 years and 0 months. This means that the estimated ARs apply to children who have just reached that age. For children aged 2 years and 6 months, the AR will be between the values of children aged 2 years and children aged 3 years.

EFSA's decision to derive ARs for multiple PAL values for children aged 4 years and older is adopted by the Committee, because of the considerable influence of physical activity on the daily energy requirement and the large individual differences in physical activity level. Deriving ARs for energy according to multiple PAL values better reflects the variation in (and range of) energy requirements within the population.

There are very few recent (DLW) data available to determine the average PAL value and the distribution of PAL values for Dutch children. EFSA used the SACN children's dataset.[13] This is the largest dataset as compared to the datasets used in the other reports and the IAEA database. Although the SACN children's dataset comprises data of mostly US and British children, which data may not be representative of Dutch children with respect to the level of physical activity, the Committee sees no better alternative. Therefore, the Committee follows EFSA's approach.

Using Dutch figures, the Committee considered the two options for taking into account the energy deposition during growth: applying either an additive factor of 2 kcal per gram of weight gain or a multiplication factor of 1.01. The results are presented in **Annex E**. When taking 2 kcal per gram of weight gain as the energy requirement for growth, this corresponds to 0.2 to 1.9% of TEE (mean: 1.0%) in boys and 0.1 to 2.1% (mean: 1.0%) in girls, per age category (1-2 y through 17-18 y). This is similar to the proposed multiplication factor of 1%. The difference in AR (means) based on either the additive factor or multiplication factor ranges from 0 to 27 kcal/d in boys and from 0 to 24 kcal/d in girls, depending on the age category. Because of the very small differences, the Committee follows EFSA's approach and uses a multiplication factor for growth of 1.01, as it is easier to apply.

### 4.3.4 Summary

The Committee adopts EFSA's approach for deriving the average energy requirement for children, but applies Dutch reference values for body weight and height, because Dutch people are on average taller and thus slightly heavier than other Europeans. Thus, the Committee determines the AR for children as the product of the predicted REE, a PAL value and the multiplication factor for growth of 1.01. REE is estimated using the prediction equations developed by Henry (2005).[15] For children aged 1-3 years, one AR is determined using a PAL value of 1.4. For children aged 4 years and older, ARs are determined for three PAL values (1.4, 1.6 and 1.8 for the age group of 4-9 years and 1.6, 1.8 and 2.0 for the age group of 10-17 years). The final ARs for energy for children from the Netherlands (rounded to the nearest 10 kcal) are shown in **Table 6**.

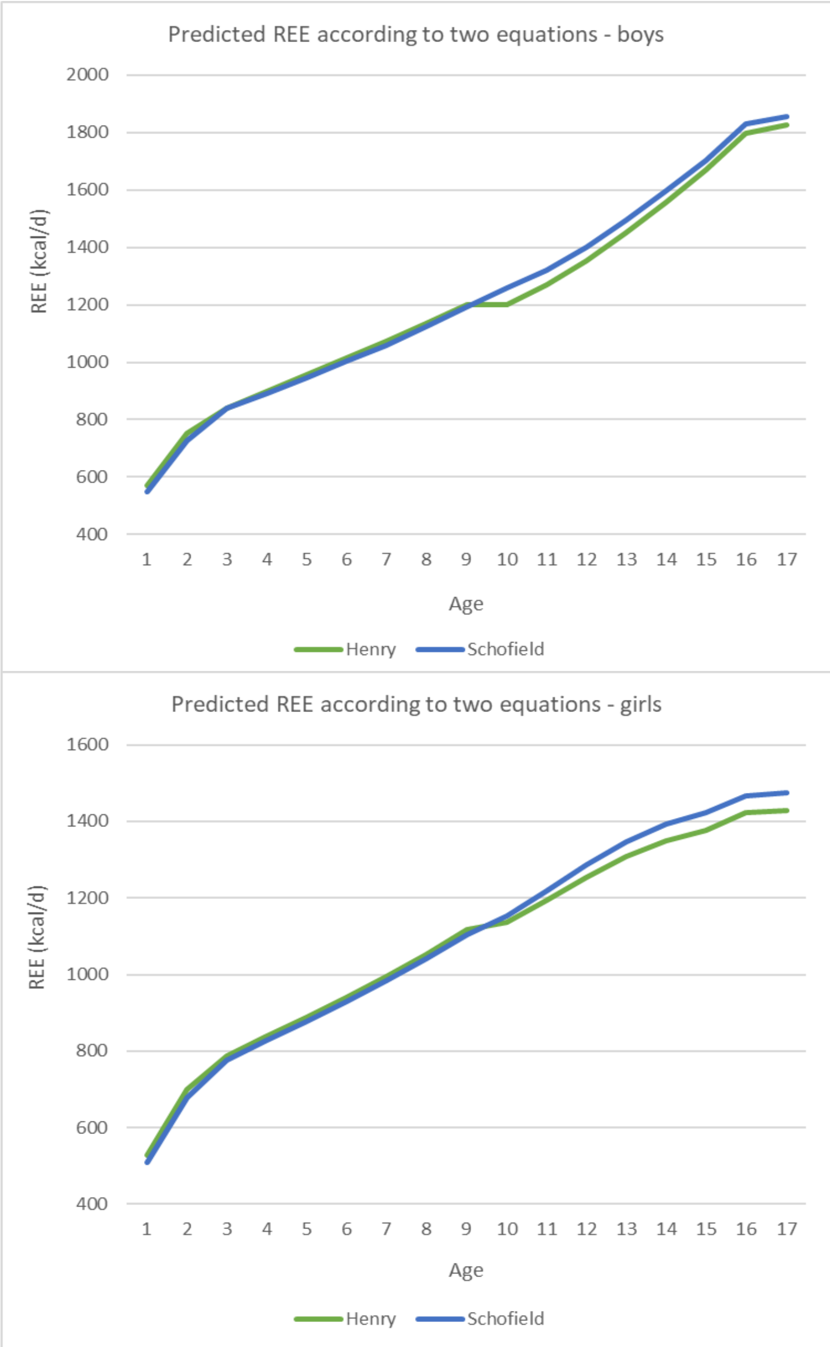


**Figure 3** Predicted REE in boys and girls, according to the prediction equations developed by Henry (2005)[15] and Schofield (1985)[30] and by using Dutch reference values for body weight and height

**Table 5** Overview of the criteria on which the average energy requirement for children is based by EFSA and other national and international organisations

| Organisation | Age (y) | Method of derivation of AR | Method of estimation of BEE or REE (or TEE) | Method of derivation of PAL | Method of derivation of energy requirement for growth (accretion costs) |
|---|---|---|---|---|---|
| EFSA, 2013[6] | 1 to <18 (one-year intervals) | AR = predicted REE * PAL value * growth factor<br><br>ARs were provided according to sex and age, and for one to three PAL values (without specifying one most appropriate PAL value). | The average REE was estimated using the sex- and age-specific prediction equations developed by Henry,[15,a] based on (reference) body weights and heights. | DLW studies were used to determine (age-specific) ranges of PAL values for different levels of physical activity. PAL values with equal intervals were defined within the observed range of PAL values associated with a sustainable lifestyle (by using the SACN children's dataset[13,b]), and those values were used for calculating the ARs: 1-3 y: 1.4; 4-9 y: 1.4, 1.6 and 1.8; and 10-17 y: 1.6, 1.8 and 2.0. | The amount of energy deposited in newly formed tissue during growth was estimated to be similar to a 1% increase in PAL (according to FAO/WHO/UNU (2004)). It was thus accounted for by applying a multiplication factor of 1.01. |
| HCNL, 2001[7] | 1 to 3,<br>4 to 8,<br>9 to 13,<br>14 to <19 | AR = predicted REE * PAL value + energy deposited for growth<br><br>ARs were provided according to sex and age, and for one PAL value. | The average REE was estimated using the prediction equations developed by Schofield (1985),[30] based on (reference) body weight. | DLW studies were used to determine age- and sex-specific PAL values, and those values were used for calculating the ARs:[59,c] 1-3 y: 1.5; 4-8 y: 1.6; 9-13 y: 1.8; and 14-18 y: ♂ 1.8 and ♀ 1.7. | The estimated amount of energy deposited as protein and fat in newly formed tissue (in kJ/g) was calculated from the estimated bodily percentages of protein and fat (using a multi-component body composition model[55]) of children aged 1, 4 and 9 y and energy contents of protein and fat.[d] The values retrieved were applied to (reference) body weight at the respective ages. Assumptions were made regarding the body composition at the ages of 14 and 18 y. |

| | | | | | |
|---|---|---|---|---|---|
| FAO/WHO/UNU, 2004[8] | 1 to <18 (one-year intervals) | AR = predicted TEE + energy deposited for growth<br><br>ARs were provided according to sex and age. For children aged ≥6 y, ARs were also provided for three PAL values. | FAO/WHO/UNU estimated TEE instead of REE. The average TEE was estimated using the sex-specific prediction equations developed by Torun (2005),[58] derived from DLW and HRM data in children aged 1-18 y. TEE was predicted as a function of (reference) body weight. [e] | PAL is included in TEE, and thus the AR is applicable to children with an average PAL value. Mean (age-specific) PAL values were derived by dividing predicted TEE by predicted BEE (estimated with Schofield's equations[30]). For children aged ≥6 y, age-specific lower and higher PAL values were defined by subtracting or adding 15% from/to the mean PAL, respectively. (Separate PAL values were defined for boys and girls and for each year of age. PAL values are in the range of 1.30-1.60, 1.55-1.85 and 1.80-2.15, depending on the sex and age category, for light, moderate and strenuous physical activity, respectively.) | The estimated amount of energy deposited as protein and fat in newly formed tissue (2 kcal/g of weight gain) was calculated from the estimated bodily protein and fat percentages (using a multi-component body composition model in healthy, normally-growing term infants up to 2 y[46,47,f]) and energy contents of protein and fat.[d] The values retrieved were applied to (reference) body weight gains.<br>This value was estimated to be equal to a 1% increase in PAL for each age group. |
| IoM, 2005[9] | 3 to <19 (one-year intervals) | AR = predicted TEE + energy deposited for growth<br><br>ARs were provided according to sex and age, and for four PAL values. | IoM estimated TEE instead of REE. The average TEE was estimated using its own sex-specific prediction equations,[9] derived from DLW data on children aged 3-18 y. TEE was predicted as a function of age, (reference) body weight, height and a PAL value.[9,g] | DLW studies (a dataset compiled by IoM[9]) and predicted BEE were used to determine ranges of PAL values for four different levels of physical activity: sedentary: ≥1.0 to <1.4; low active: ≥1.4 to <1.6; active: ≥1.6 to <1.9; and very active: ≥1.9 to <2.5. A physical activity coefficient (corresponding to one of the four PAL categories) was included in the prediction equation for TEE. | The estimated amount of energy deposited as protein and fat in newly formed tissue was calculated from the estimated protein and fat gains (using a multi-component body composition from measured protein and fat gains in healthy, normally growing children[55,61]) and the energy contents of protein and fat.[d] Those values were applied to reference body weight gains.[62] Energy deposition during childhood was estimated to be on average 20 kcal/d in children aged 3 to <9 y and 25 kcal/d in children aged 9 to <19 y. |

| | | | | | |
|---|---|---|---|---|---|
| NCM, 2014[10] | 2 to <18 (one-year intervals) | AR = predicted REE * PAL value<br><br>ARs were provided according to sex and age, and for three PAL values. | The average REE was estimated using the sex- and age-specific prediction equations developed by Henry,[15] based on (reference) body weight and height. | DLW studies were used to determine (age-specific) PAL values for three different levels of physical activity. The 25th, 50th and 75th percentile of the age-specific distribution of PAL-values from the SACN database[13] were considered low, average and high levels of physical activity, respectively: 2-3 y: 1.35, 1.39 and 1.43; 4-9 y: 1.42, 1.57 and 1.69; 10-17 y: 1.66, 1.73 and 1.85. | N/A |
| DACH, 2015[11,12] | 1 to <4,<br>4 to <7,<br>7 to <10,<br>10 to <13,<br>13 to <15,<br>15 to <19 | AR = predicted REE * PAL value * growth factor<br><br>ARs were provided according to sex and age category, and for two to four PAL values. | The average REE was estimated using the sex- and age-specific prediction equations developed by Henry,[15,a] based on (reference) body weight and height. | DACH used two to four generalised PAL values to calculate ARs: 1-3 y: 1.4 and 1.6; 4-9 y: 1.4, 1.6 and 1.8; 10-18 y: 1.4, 1.6, 1.8 and 2.0. These values were most likely obtained from EFSA, and are thus based on DLW data. | The amount of energy deposited in newly-formed tissue during growth was estimated to be similar to a 1% increase in PAL (according to FAO/WHO/UNU (2004)). It was thus accounted for by applying a multiplication factor of 1.01. |
| SACN, 2011[13] | 1 to <19 (one-year intervals) | AR = predicted REE * PAL value * growth factor<br><br>ARs were provided according to sex and age, and for three PAL values. The median PAL value was assumed to be the population average. | The average REE was estimated using the sex- and age-specific prediction equations developed by Henry,[15,a] based on (reference) body weight and height. | DLW studies (a dataset compiled by SACN; the SACN children's dataset[13,b]) were used to determine (age-specific) PAL values for three different levels of physical activity. The 25th, 50th and 75th percentile of the age-specific distribution of PAL values observed were considered low, average and high levels of physical activity, respectively: 1-3 y: 1.35, 1.39 and 1.43; 4-9 y: 1.42, 1.57 and 1.69; 10-18 y: 1.66, 1.73 and 1.85. | The amount of energy deposited in newly-formed tissue during growth was estimated to be similar to a 1% increase in PAL (according to FAO/WHO/UNU (2004)). It was thus accounted for by applying a multiplication factor of 1.01. |

AR: average requirement; BEE: basal energy expenditure; d: days; DACH: German-speaking countries Germany (Deutschland), Austria and Switzerland (Confoederatio Helvetica); DLW: doubly-labelled water; EFSA: European Food Safety Authority; FAO/WHO/UNU: Food and Agriculture Organisation of the United Nations/World Health Organisation/United Nations University; g: grams; HCNL: Health Council of the Netherlands; HRM: heart rate monitoring; IoM: Institute of Medicine; kcal: kilocalories; kJ: kilojoules; NCM: Nordic Council of Ministers; PAL: physical activity level; REE: resting energy expenditure; SACN: Scientific Advisory Committee on Nutrition; TEE: total energy expenditure; USA: United States of America; y: years

[a] The prediction equations developed by Henry (2005) have overlapping age bands (0-3, 3-10 and 10-18 years).[15] EFSA and SACN used the prediction equations for 3-10-year-olds for those aged 3 y and the equation for the 10-18-year-olds for those aged 10 y. DACH used the prediction equation for 0-3-year-olds for those aged 1 to <4 y, the equation for 3-10-years-olds for those aged 4 to <10 y and the equation for 10-18-year-olds for those aged 10 to <19 y.

[b] SACN compiled a dataset of all published DLW studies in (well-nourished) children aged over 1 y, including all studies assembled by Torun (2005)[58] and other studies published up to 2006. The dataset included 170 data points (study means) representing 3502 individual measurements (59% female).

[c] Datasets from the Netherlands, the UK and the USA.

[d] Energy values of 23.6 kJ (5.65 kcal) per gram of deposited protein and 38.7 kJ (9.25 kcal) per gram of deposited fat were used for the calculation.

[e] FAO/WHO/UNU recommends reducing the TEE estimates for children of 1 and 2 y old by 7% to fit the energy requirements of infants.

[f] FAO/WHO/UNU assumed that the composition of growing tissue does not change much between end of infancy and onset of puberty.

[g] IoM developed prediction equations for TEE based on its own dataset of DLW studies that were all conducted in the USA (n=525 normal-weight, mostly Caucasian children).

**Table 6** Average energy requirements and their components for children (1 up to and including 17 years) from the Netherlands[a,b]

| Sex | Age (y) | Dutch reference weight (kg) | Dutch reference height (cm) | Predicted REE (kcal/d)[c] | Predicted REE and energy for growth[e] | AR (kcal/d)[a,f] at PAL=1.4 | AR (kcal/d)[a,f] at PAL=1.6 | AR (kcal/d)[a,f] at PAL=1.8 | AR (kcal/d)[a,f] at PAL=2.0 |
|---|---|---|---|---|---|---|---|---|---|
| Boys | 1 | 10.1 | 76.7 | 573 | 578 | 810 (810) | – | – | – |
| Boys | 2 | 12.9 | 88.4 | 752 | 760 | 1060 (1064) | – | – | – |
| Boys | 3 | 15.2 | 97.8 | 842[d] | 850 | 1190 (1190) | – | – | – |
| Boys | 4 | 17.3 | 105.5 | 898[d] | 907 | 1270 (1269) | 1450 (1450) | 1630 (1632) | – |
| Boys | 5 | 19.6 | 113.2 | 956[d] | 966 | 1350 (1352) | 1550 (1546) | 1740 (1739) | – |
| Boys | 6 | 22.0 | 119.9 | 1014[d] | 1024 | 1430 (1433) | 1640 (1638) | 1840 (1843) | – |
| Boys | 7 | 24.5 | 126.2 | 1071[d] | 1082 | 1520 (1515) | 1730 (1731) | 1950 (1947) | – |
| Boys | 8 | 27.4 | 132.5 | 1135[d] | 1146 | 1600 (1604) | 1830 (1834) | 2060 (2063) | – |
| Boys | 9 | 30.5 | 138.5 | 1172[c,d] | 1183 | 1660 (1657) | 1890 (1894) | 2130 (2130) | – |
| Boys | 10 | 33.5 | 143.7 | 1233[c] | 1245 | – | 1990 (1992) | 2240 (2241) | 2490 (2490) |
| Boys | 11 | 36.9 | 149.0 | 1271 | 1284 | – | 2050 (2054) | 2310 (2311) | 2570 (2567) |
| Boys | 12 | 41.3 | 155.2 | 1356 | 1370 | – | 2190 (2191) | 2470 (2465) | 2740 (2739) |
| Boys | 13 | 46.5 | 161.8 | 1455 | 1469 | – | 2350 (2351) | 2650 (2645) | 2940 (2939) |
| Boys | 14 | 52.2 | 168.5 | 1562 | 1577 | – | 2520 (2523) | 2840 (2839) | 3150 (3154) |
| Boys | 15 | 58.3 | 175.2 | 1675 | 1691 | – | 2710 (2706) | 3040 (3044) | 3380 (3383) |
| Boys | 16 | 65.7 | 179.1 | 1800 | 1818 | – | 2910 (2909) | 3270 (3273) | 3640 (3637) |
| Boys | 17 | 67.2 | 181.0 | 1829 | 1847 | – | 2960 (2955) | 3330 (3325) | 3690 (3694) |
| Girls | 1 | 9.5 | 75.0 | 529 | 534 | 750 (748) | – | – | – |
| Girls | 2 | 12.3 | 87.1 | 699 | 706 | 990 (989) | – | – | – |
| Girls | 3 | 14.7 | 97.0 | 786 | 794 | 1110 (1112) | – | – | – |
| Girls | 4 | 16.9 | 104.9 | 838 | 846 | 1190 (1185) | 1350 (1354) | 1520 (1523) | – |
| Girls | 5 | 19.1 | 112.1 | 888 | 897 | 1260 (1256) | 1440 (1435) | 1620 (1615) | – |
| Girls | 6 | 21.5 | 118.8 | 940 | 950 | 1330 (1330) | 1520 (1520) | 1710 (1710) | – |
| Girls | 7 | 24.1 | 125.3 | 995 | 1005 | 1410 (1407) | 1610 (1608) | 1810 (1809) | – |
| Girls | 8 | 26.9 | 131.3 | 1052 | 1063 | 1490 (1488) | 1700 (1701) | 1910 (1913) | – |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Girls | 9 | 30.1 | 137.3 | 1101[c] | 1112 | 1560 (1557) | 1780 (1780) | 2000 (2002) | – |
| Girls | 10 | 34.0 | 143.5 | 1165[c] | 1177 | – | 1880 (1883) | 2120 (2118) | 2350 (2353) |
| Girls | 11 | 38.4 | 149.7 | 1196 | 1208 | – | 1930 (1932) | 2170 (2174) | 2420 (2415) |
| Girls | 12 | 43.2 | 155.7 | 1256 | 1268 | – | 2030 (2029) | 2280 (2283) | 2540 (2537) |
| Girls | 13 | 47.6 | 160.8 | 1310 | 1323 | – | 2120 (2117) | 2380 (2381) | 2650 (2646) |
| Girls | 14 | 51.0 | 164.5 | 1351 | 1365 | – | 2180 (2183) | 2460 (2456) | 2730 (2729) |
| Girls | 15 | 53.2 | 166.9 | 1378 | 1391 | – | 2230 (2226) | 2510 (2505) | 2780 (2783) |
| Girls | 16 | 57.8 | 168.3 | 1424 | 1439 | – | 2300 (2302) | 2590 (2590) | 2880 (2877) |
| Girls | 17 | 58.3 | 169.2 | 1431 | 1446 | – | 2310 (2313) | 2600 (2602) | 2890 (2891) |

AR: average requirement; cm: centimetres; kcal/d: kilocalories per day; kg: kilograms; MJ/d: megajoules per day; PAL: physical activity level; REE: resting energy expenditure; y: years

[a] ARs are rounded to the nearest 10 kcal. Values as calculated, before rounding, are shown between brackets.

[b] AR = predicted REE * PAL * growth factor

[c] REE was estimated with the sex- and age-specific prediction equations developed by Henry (2005), based on body weight and height.[15] Like EFSA, the Committee uses the prediction equations for 3-10-year-olds for children aged 3 years. For children aged 9 years and 10 years, it uses the average of the values obtained using the REE prediction equations for the 3-10-year-olds and those for the 10-18-year-olds.

[d] There seems to be an error in Henry's equation for REE in kcal/d for 3-10-year-old boys. Therefore, for this group, Henry's equation for REE in MJ/d was used and REE was converted into kcal/d as follows: REE in MJ/d / 4.184 * 1000.

[e] Calculated as predicted REE * 1.01 (growth factor).

[f] Like EFSA, the Committee applied a PAL value of 1.4 for the age group of 1-3 y, PAL-values of 1.4, 1.6 and 1.8 for the age group of 4-9 y and 1.6, 1.8 and 2.0 for the age group of 10-17 y.

## 4.4 Pregnant women

**Table 7** provides an overview of the criteria on which EFSA and the other organisations based their additional energy requirements for pregnant women.

### 4.4.1 EFSA's approach and considerations and comparison with other organisations

*General approach*

EFSA used an additive model to derive requirements for pregnant women, which means that it set an *additional requirement*. This together with the AR for non-pregnant, non-lactating women results in the AR for pregnant women. Additional requirements were specified per trimester since the accretion of tissue mass (and thus the energy stored in these tissues) is not equally distributed throughout pregnancy. The additional requirements were calculated as the cumulative increment in TEE plus the energy deposited as protein and fat in newly formed maternal and foetal tissues. The average increment in TEE was obtained from longitudinal DLW measurements in free-living, well-nourished (pregnant) women.[63,64] The increment in TEE comprises any gestational changes in REE (which includes the increased energy required for maintenance of increased tissue mass), TEF or EEPA. The energy deposited in growing tissues was calculated using average protein and fat gains (estimated using body composition models) during pregnancy[63,64] and applied to the reference body weight gain.

All organisations used the same general approach as EFSA. They used the additive model and calculated additional requirements for pregnant women, which were calculated based on the cumulative increment in TEE (or REE) and the energy deposited in growing tissues. SACN also considered energy intake during pregnancy.

The HCNL report (2001) was published before some publications[64,65] that EFSA used to derive reference values for pregnant women. This report is therefore considered outdated and not further described in this section.

Most of the organisations derived additional requirements per trimester. EFSA and NCM set additional requirements for each of the three trimesters. IoM and DACH considered the additional energy requirement for the first trimester to be negligible, and SACN for the first and second trimester. All of them, with the exception of SACN, therefore set recommendations for the second and third trimester only. FAO/WHO/UNU added the additional requirement in trimester 1 to the requirement in trimester 2.

*Cumulative increment in total energy expenditure*

EFSA, DACH and NCM obtained values for the cumulative increment in TEE per trimester directly from a review of longitudinal DLW measurements in (pregnant) women.[64] Based on this review and some other studies (e.g. [66]), EFSA concluded that TEF, when expressed as percentage of energy intake, is on average unchanged or slightly lower throughout pregnancy compared to pre-pregnancy.[64] EFSA also concluded that there is no conclusive evidence of a change in EEPA on average during pregnancy.[6,64,66] Therefore, EFSA assumed that any change in TEE is caused primarily by a change in REE, although considerable inter-individual variation exists.

The approaches of FAO/WHO/UNU, IoM and SACN were (slightly) different. FAO/WHO/UNU calculated the additional requirement based on two approaches and averaged the two calculations to arrive at the recommended additional requirement. The additional requirement was calculated first as the cumulative increment in TEE plus the energy deposited in growing tissues, and second as the cumulative increment in BEE plus the energy deposited in growing tissues, with an adjustment for the efficiency of energy utilisation for protein and fat synthesis (assumed to be 90%). TEE and BEE data were obtained from the same studies, as described in the review used by EFSA.[64] The Committee notes that the average increment in BEE was quite close to the increment in TEE. Throughout pregnancy, BEE was only 600 kcal higher than TEE, which would result in a higher additional requirement of only 2 kcal/d.

IoM estimated the average change in TEE per gestational week (8 kcal/week) based on its own DLW database of pregnant women with healthy pre-pregnancy BMIs. The cumulative increment in TEE was then calculated for each trimester as 8 kcal/week multiplied by the midpoint of the number of weeks of the respective trimester. A later study by Butte et al. (2004) supported the linear increase in TEE during pregnancy (7.4 ± 10.2 kcal/week).[65]

SACN decided that estimating additional energy requirements for pregnant women from measured or predicted TEE plus energy deposition (like EFSA, FAO/WHO/UNU, IoM, DACH and NCM) would result in values that were too high, based in part on the observation that those values exceed energy intakes of well-nourished pregnant women (even when allowances are made for underreporting of energy intake). Furthermore, SACN argues that in the first trimester, weight gain is limited and will minimally affect REE. In the second and third trimester, the increase in REE due to weight gain might be compensated by a decrease in physical activity. Lastly, SACN argues that gestational energy expenditure and deposition might be excessively driven by fat deposition since this is not a determinant of birth weight and some fat deposition remains six months *postpartum* (which may lead to undesirable weight gain). Based on this, SACN did not revise its reference values from 1991.[67] At the time, SACN estimated that pregnancy results in an additional requirement of 0.8 MJ/d (191 kcal/d), based on estimations of the cost of energy deposition and increases in BEE, and the observation that energy intake only increased in the third trimester by no more than 100 kcal/d. Separate values for each component were not reported.

*Energy deposited in growing tissues*

EFSA adopted the approach of FAO/WHO/UNU (2004) to determine the energy deposited in newly-formed tissue, i.e. protein and fat gains associated with an ideal body weight gain (12 kg[68]) were multiplied by the energy density of protein and fat. IoM, NCM and DACH also used this approach, but final values differed from those of EFSA (except for the values of DACH) due to the different reference values applied for gestational body weight gain (e.g. 13.8 kg by NCM) or a different body composition model used to estimate protein and fat gains (IoM). SACN questioned whether energy deposition should be based on fat deposition, since that is not a determinant of birth weight and some fat deposition remains six months *postpartum*. Therefore, it stuck to the additional requirements of its previous report from 1991 (the amount of energy required for growth was not specified in this report).[67]

### 4.4.2 The Committee's conclusions for the Netherlands

The Committee agrees with EFSA's derivation of additional requirements for pregnant women (additive model), based on the cumulative increment in TEE and the energy required for growth, and with the specification of additional requirements per trimester.

The Committee agrees with the use of longitudinal studies of TEE measured using the DLW method in (pregnant) women to estimate the cumulative increment in TEE, as did EFSA, DACH and NCM. The Committee prefers EFSA's approach of using the cumulative increase in TEE over FAO/WHO/UNU's approach of using the average of the additional requirements based on either the cumulative increment in BEE or the cumulative increment in TEE. The Committee considers TEE, in principle, a better measure of energy expenditure than BEE as TEE includes more components of energy expenditure than BEE.

The reports were quite similar with respect to the calculation of the energy deposited in newly-formed tissue: protein and fat gains associated with an ideal gain in body weight were multiplied by the energy content of protein and fat. The Committee has no objections to EFSA's approach. IoM used a different (older) body composition model to estimate protein and fat gains compared to EFSA, which can explain their different values. The Committee applies the values for protein and fat gains obtained from the more recent models, as described by EFSA.

The Committee uses a gestational weight gain of 13.8 kg as a reference (instead of 12.0 kg used by EFSA), which is consistent with its previous advisory reports describing DRVs for pregnant women[4,5] and supported by a recent individual participant-level meta-analysis of 196,670 participants from 25 cohort studies from Europe and North America.[69,70] The reference value of 13.8 kg was also applied by

NCM. It is worth noting that the optimal range of gestational weight gain depends on the pre-pregnancy BMI. The value of 13.8 kg applies to well-nourished women with a healthy pre-pregnancy BMI (18.5-25 $kg/m^2$). The optimal gestational weight gain is higher in the case of underweight before pregnancy and lower if pre-pregnancy BMI exceeds the healthy range.[69]

It is important to note that the average requirements derived in this advisory report apply to both adolescent and adult pregnant women and to singleton pregnancies. Women with a multiple pregnancy probably have a higher energy requirement than those with a singleton pregnancy.

#### 4.4.3 Summary

The Committee adopts EFSA's approach for the derivation of additional energy requirements for pregnant women, with the exception that it uses a different optimal gestational weight gain (13.8 kg) than EFSA (12 kg). The additional requirement, per trimester, is calculated as the cumulative increment in TEE plus the energy deposited in growing tissues. The Committee's derivation of the additional requirement and the final values (rounded to the nearest 10 kcal) for pregnant women from the Netherlands are shown in **Table 8**.

**Table 7** Overview of the criteria on which the additional energy requirement for pregnant women is based by EFSA and other national and international organisations

| Organisation | Trimester | Additional requirement (kcal/d)[a] | Method of derivation of additional requirement[a] | Cumulative increment in TEE (or BEE) (kcal/d) | Method of derivation of cumulative increment in TEE (or REE) | Energy deposited in growing tissues (kcal/d) | Reference weight gain | Method of derivation of energy deposited in growing tissues |
|---|---|---|---|---|---|---|---|---|
| EFSA, 2013[6] | 1<br>2<br>3 | 70<br>260<br>500 | Additional requirement = cumulative increment in TEE + energy deposited in growing tissues | 20<br>85<br>310 | Longitudinal DLW measurements of TEE in free-living, well-nourished women (who became pregnant) in Sweden, the UK and the USA were used to estimate average increments in TEE.[64] | 48<br>182<br>185 | 12 kg | The estimated amount of energy deposited as proteins and fat in newly-formed foetal and maternal tissue was calculated from gains in protein (597 g) and fat (3.7 kg) estimated from longitudinal body composition measurements during pregnancy.[64,b] |
| HCNL, 2001[7] | 1<br>2<br>3 | 290<br>290<br>290<br><br>The additional requirement was calculated as the mean of the additional requirements in each of the 3 trimesters. | Additional requirement = cumulative increment in TEE + energy deposited in growing tissues | -48<br>48<br>502 | Longitudinal DLW measurements of TEE in 69 free-living, well-nourished women (who became pregnant) from Sweden[71], the UK[72] and the USA[73] were used to estimate average (weighed mean) increments in TEE. | 95<br>165<br>120 | 3.0 kg in fat mass | The estimated amount of energy deposited as fat in newly formed foetal and maternal tissue, applied to an average gestational increase in fat of 3.0 kg.[66] |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| FAO/WHO/UNU, 2004[8] | 1<br>2<br>3 | 0<br>360<br>475<br><br>FAO/WHO/UNU recommends adding together the additional requirements of trimester 1 and 2. | Additional requirement = cumulative increment in BEE or TEE + energy deposited in growing tissues<br><br>The average of the calculation based on the increment in BEE and the calculation based on the increment in TEE was used. | 20 (and BEE[c]: 48)<br>85 (and BEE[c]: 95)<br>310 (and BEE[c]: 237) | Longitudinal measurements of BEE in studies of well-nourished women with adequate weight gains during pregnancy who gave birth to infants with adequate weights were used to calculate average increments in BEE. Longitudinal DLW measurements of TEE in free-living, well-nourished women (who became pregnant) in Sweden, the UK and the USA were used to estimate average increments in TEE. | 48<br>182<br>185 | 12 kg | The estimated amount of energy deposited as proteins and fat in newly-formed foetal and maternal tissue was calculated from gains in protein (597 g) and fat (3.7 kg) estimated from longitudinal studies of body composition during pregnancy.[64,b] |
| IoM, 2005[9] | 1<br>2<br>3 | 0<br>340<br>452 | Additional requirement = cumulative increment in TEE + energy deposited in growing tissues | 0<br>160<br>272 | Longitudinal DLW measurements of TEE in a dataset of pregnant women with normal pre-pregnancy BMI (18.5-25 kg/m$^2$) were used to estimate the median of the average change in TEE per gestational week (8 kcal/wk). The midpoint of the number of weeks per trimester was used for calculations (i.e. 20 and 34 weeks for the 2nd and 3rd trimester, respectively). | 0<br>180<br>180 | Pre-pregnancy BMI of 18.5-25 kg/m$^2$ | The estimated amount of energy deposited as proteins and fat in newly formed foetal and maternal tissue was calculated from the theoretical estimated protein deposition (925 g)[74] and average fat deposition (3.7 kg) measured in longitudinal studies of body composition during pregnancy.[9] |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NCM, 2014[10] | 1<br>2<br>3 | 103<br>329<br>537 | Additional requirement = cumulative increment in TEE + energy deposited in growing tissues<br><br>Average of the calculation based on the increment in BEE and the calculation based on the increment in TEE was used. | Values NR.<br><br>NCM considered both the increment in BEE and the increment in TEE (similar to FAO/WHO/UNU 2004). | Longitudinal measurements of BEE in studies of well-nourished women with adequate weight gains during pregnancy who gave birth to infants with adequate weights were used to calculate average increments in BEE. Longitudinal DLW measurements of TEE in free-living, well-nourished women (who became pregnant) in Sweden, the UK and the USA were used to estimate average increments in TEE.[e] | 55<br>209<br>213 | 13.8 kg | The estimated amount of energy deposited as proteins and fat in newly formed foetal and maternal tissue was calculated from gains in protein (686 g) and fat (4.3 kg) estimated from longitudinal studies of body composition during pregnancy.[64,d] |
| DACH, 2015[11,12] | 1<br>2<br>3 | None.[e]<br>250<br>500<br><br>Values were rounded. Values apply to women whose PAL does not change during pregnancy. | Additional requirement = cumulative increment in TEE + energy deposited in growing tissues | 20<br>85<br>310 | Longitudinal DLW measurements of TEE in free-living, well-nourished women (who became pregnant) in Sweden, the UK and the USA were used to estimate average increments in TEE (according to FAOWHO/UNU 2004).[e] | 48<br>182<br>185 | 12 kg | The estimated amount of energy deposited as proteins and fat in newly formed foetal and maternal tissue was calculated from gains in protein (597 g) and fat (3.7 g) estimated from longitudinal studies of body composition during pregnancy.[64,b] |
| SACN, 2011[13] | 1<br>2<br>3 | None.<br>None.<br>191 | Values adopted from its previous report (COMA 1991[67])[f], based on estimations of the costs of energy deposition and increases in BEE, and the observation that energy intake only increased in the third trimester by no more than 100 kcal/d. | NA | NA | NA | 12 kg | NA |

AR: average requirement; BEE: basal energy expenditure; COMA: Committee on Medical Aspects of Food and Nutrition Policy; d: days; DACH: German-speaking countries Germany (Deutschland), Austria and Switzerland (Confoederatio Helvetica); EFSA: European Food Safety Authority; FAO/WHO/UNU: Food and Agriculture Organisation of the United Nations/World Health Organisation/United Nations University; g: grams; HCNL: Health Council of the Netherlands; IoM: Institute of Medicine; kcal: kilocalories; NA: not applicable; NCM: Nordic Council of Ministers; PAL: physical activity level; REE: resting energy expenditure; SACN: Scientific Advisory Committee on Nutrition; TEE: total energy expenditure; y: years

[a] Generally, organisations calculate an 'additional requirement' for pregnant women, which is the extra amount of energy needed during pregnancy. This additional requirement should be added to the AR for non-pregnant, non-lactating women (assuming that PAL does not change during pregnancy).

[b] Distribution of protein deposition was estimated as 0% in the 1st trimester, 20% (1.3 g/d) in the 2nd trimester and 80% (5.1 g/d) in the 3rd trimester. Distribution of fat deposition was estimated as 11% (5.2 g/d) in the 1st trimester, 47% (18.9 g/d) in the 2nd trimester and 42% (16.9 g/d) in the 3rd trimester. Energy values of 5.65 kcal per gram of deposited protein and 9.25 kcal per gram of deposited fat were used for calculation.

[c] In calculations based on BEE, an efficiency of food energy utilisation for protein and fat deposition of 90% was taken into account. This factor was not applied in calculations based on TEE, as the energy cost of synthesis is included in DLW measurements of TEE.

[d] Distribution of protein deposition was estimated as 0% in the 1st trimester, 20% (1.5 g/d) in the 2nd trimester and 80% (5.9 g/d) in the 3rd trimester. Distribution of fat deposition was estimated as 11% (6.0 g/d) in the 1st trimester, 47% (21.7 g/d) in the 2nd trimester and 42% (19.4 g/d) in the 3rd trimester. Energy values of 5.65 kcal per gram of deposited protein and 9.25 kcal per gram of deposited fat were used for calculation.

[e] The additional energy intake of 70 kcal/d for the first trimester was considered negligible and could be disregarded.

[f] SACN notes that the approach used by FAO/WHO/UNU (2004) and IoM (2005) leads to estimates of the additional energy requirement that exceed the increase in energy intakes observed in populations of well-nourished pregnant women giving birth to infants with a body weight in the healthy range. SACN argues, among other things, that compensatory reductions in EEPA likely occur during the 2nd and 3rd trimester and that these reduce the demand for extra energy. Therefore, its previous recommendations from 1991 were not revised.

**Table 8** Additional energy requirements and their components for pregnant women from the Netherlands[a,b]

| Trimester | Protein deposition (g/d)[c] | Fat deposition (g/d)[c] | Energy deposited in growing tissues (kcal/d)[d] | Cumulative increment in TEE (kcal/d)[e] | Additional requirement (kcal/d)[a] |
|---|---|---|---|---|---|
| 1 | 0 | 6.0 | 55.5 | 23.9 | 80 (79) |
| 2 | 1.5 | 21.7 | 209.2 | 95.6 | 310 (305) |
| 3 | 5.9 | 19.4 | 212.8 | 358.5 | 570 (571) |

g/d: grams per day; kcal/d: kilocalories per day; kJ/d: kilojoules per day; TEE: total energy expenditure

[a] ARs are rounded to the nearest 10 kcal. Values as calculated, before rounding, are presented between brackets.

[b] Additional requirement = cumulative increment in TEE + energy deposited in growing tissues.

[c] Values obtained from Butte & King (2005),[64] based on a total gestational weight gain of 13.8 kg.

[d] Energy deposited in growing tissues = (protein deposition * 5.65) + (fat deposition * 9.25). Energy values of 5.65 kcal per gram of deposited protein and 9.25 kcal per gram of deposited fat were used.

[e] Values obtained from Butte & King (2005)[64] and converted from kJ/d into kcal/d by dividing by 4.184.

## 4.5 Lactating women

**Table 9** provides an overview of the criteria on which EFSA and the other organisations based their additional energy requirements for lactating women.

### 4.5.1 EFSA's approach and comparison with other organisations

*General approach*

EFSA adopted the approach of FAO/WHO/UNU (2004)[8] and used an additive model to derive reference values for lactating women (exclusively breastfeeding). This means that it calculated the AR for lactating women as the AR for non-pregnant, non-lactating women plus an *additional requirement*. In this approach, EFSA (in line with FAO/WHO/UNU and IoM) reasoned that the TEE of non-pregnant, non-lactating women is applicable to lactating women since the REE and the metabolic efficiency of performing physical activities of lactating women do not change (or only change slightly) compared to the women's pre-pregnant, non-lactating state, and because most women resume their usual level of physical activity shortly after the baby is born (usually in the first month *postpartum*).[6,8,64] FAO/WHO/UNU stated that it could be argued that maternal physical activity is reduced in periods in which babies are exclusively breastfed, resulting in a lower TEE. But this lower physical activity level might be compensated by the increased workload when the mother is carrying her infant while moving around. Therefore, FAO/WHO/UNU assumed that the EEPA does not change during lactation compared to the pre-pregnancy levels.[8]

EFSA decided to not base the AR for lactating women on the TEE measured using the DLW method, because the DLW method may not be reliable in lactation studies and because the sample size of the available studies was rather small. According to EFSA, the limited reliability of the DLW method in lactation studies has to do with potential sources of error attributed to the exchange and sequestration of isotopes that occurs during the *de novo* synthesis of milk fat and lactose, and to the increased water flux into milk.[6,75]

EFSA adopted the approach of FAO/WHO/UNU (2004) to estimate the additional requirement for exclusively breastfeeding women on the basis of two factors: 1) the energy required for the production of breast milk and; 2) the energy released when maternal tissue stores accumulated during pregnancy are used up after giving birth. The energy required for milk production minus the energy released from maternal tissue due to weight loss yields the additional requirement. The average amount of energy required for milk production was based on the measured mean milk production, the energy density of milk and an energy conversion factor. The average amount of energy that is released from maternal tissue was calculated from the average amount of weight loss during lactation and the energy density of body tissue.

All organisations used the additive model, like EFSA, and derived additional energy requirements for lactating women. They also applied the same approach as EFSA and FAO/WHO/UNU for deriving the additional requirement, i.e. by subtracting the energy released due to weight loss from the energy required for milk production. However, final values differed (slightly) due to different methods or datasets used to derive values for each of these two components (explained in more detail below).

EFSA set an additional requirement for the first six months after childbirth. It did not derive additional requirements for the period thereafter, because the amount of breast milk secreted varies greatly between persons as the infant's intake of breast milk is reduced depending on the intake of complementary foods. All other organisations also specified additional requirements for at least the first six months *postpartum*. HCNL in 2001, FAO/WHO/UNU, DACH and SACN did not derive additional energy requirements for lactating women after six months *postpartum*, in accordance with EFSA. By contrast, IoM set an additional requirement for 7 to 12 months *postpartum* and NCM for age categories until 24 months *postpartum*.

*Energy requirement for breast milk production*

EFSA estimated the average amount of energy required for milk production over the first six months (675 kcal/d) based on the measured mean milk production (807 g/d), the energy density of milk (0.67 kcal/g) and an energy conversion factor (80%). The energy conversion factor, or energetic efficiency, is the percentage of dietary energy that is converted into human milk and takes into account the energy expenditure for digestion, absorption, inter-conversion and transport.[6,64]

HCNL (in 2001) and DACH estimated the energy requirement for milk production in the same manner as EFSA, but used a slightly different value for the average amount of breast milk (800 and 750 ml/d compared to 807 g/d). NCM used a similar approach, but used breast milk volumes for specific age groups (0-2 and 3-5 instead of 0-5 months). IoM and SACN used a somewhat different approach for estimating the energy required for milk production: they did not apply the energy conversion factor. SACN argued that the conversion factor of 80% is unreliable and likely leads to an overestimation of the true energetic costs of the synthesis of breast milk. This could explain why the increase in energy expenditure during lactation estimated using this factorial approach is considerably greater than the increase in TEE measured in DLW studies (TEE measured using the DLW method includes the energetic costs of milk synthesis). IoM did not provide an explanation. IoM and SACN also used a slightly different value for the average amount of breast milk (780 ml/d) as it was derived from a different dataset.

*Energy released from maternal tissue*

EFSA calculated the average amount of energy that is released from maternal tissue due to postnatal weight loss (170 kcal/d) based on the average amount of weight lost by well-nourished women during the first six months *postpartum* (0.8 kg/month) and the energy density of body tissue (6.5 kcal/g).[63,64,76] It should be noted that the change in postnatal weight is highly variable among lactating women and may depend on differences in gestational weight gain and physical activity level, among other things.[76] Mean weight changes of -2.25 to +0.20 kg/month have been recorded in studies of lactating women up to 6 months *postpartum*.[76] So, the estimated value of 0.8 kg/month might be a good approximation of the energy mobilisation at group level, but can differ substantially by individual.

All organisations except HCNL in 2001 used the same approach and same underlying dataset to calculate the average amount of energy released from maternal tissue due to postnatal weight loss, estimated at 170 kcal/d. HCNL's approach was similar, but an average postnatal weight loss of 0.5 kg/month was used instead of 0.8 kg/month, resulting in an average energy release of about 145 kcal/d. The value of 0.5 kg/month applied by HCLN was obtained from studies in both developed and developing societies,[66] whereas the value of 0.8 kg/month was derived from studies in developed societies only.[76]

#### 4.5.2 The Committee's conclusions for the Netherlands

The Committee agrees with EFSA when it comes to deriving an *additional requirement* for energy for lactating women who are exclusively breastfeeding their infant for the first six months *postpartum*. It also agrees with the approach of EFSA of calculating the additional requirement based on the energy required for milk production and the energy released from maternal tissue stores. EFSA's approach is based on the approach used by FAO/WHO/UNU (2004) and is largely in line with the reports of DACH, NCM and HCNL's report from 2001.

With regard to the calculation of the energy required for milk production, the Committee agrees with EFSA's estimates for the amount of milk produced and the energy content of milk, but agrees with IoM and SACN that an energy conversion factor should not be applied, whereas EFSA and some other organisations do apply an energy conversion factor of 80%. The energy conversion factor is used to account for the energetic costs of milk synthesis (i.e. the energy expenditure for digestion, absorption, inter-conversion and transport). Those synthetic costs are included in the REE, and thus the REE would be expected to be higher in lactating women than in non-pregnant non-lactating women. However, that has not been consistently observed in longitudinal studies of REE measured in women in the non-pregnant, non-lactating state (partly pre-conception and partly post-lactation) and during lactation (**Annex F**).[71,73,75,77-79] Those studies show only small differences in REE between those states: the reported differences vary between -4 and +7% (or -51 to +92 kca/dl). On average, this indicates that REE increases slightly during lactation compared to the non-lactating state, but in all those studies the average body weight was also higher in the lactating compared to the non-lactating state. [6,9] Based on these REE measurements, the Committee assumes that no extra energy is needed for the milk synthesis. Thus, the Committee does not apply an energy conversion factor, as that would appear to result in an overestimation of REE, and thus of the total energy requirement, in lactating women. The Committee does adopt EFSA's figure for breast milk secretion of 807 g/d. The slightly different values for breast milk secretion used by some other organisations (750-800 g/d) results in only marginally different values for the energy required for milk production (maximum differences of 38 kcal/d). Moreover, the value of 807 g/d has been derived from the most recent publication and was previously used by the Committee to derive DRVs for protein.[4] For the purpose of harmonisation, the Committee deems the value used by EFSA appropriate. There seems to be international consensus that the energy density of human milk is 0.67 kcal/d, so this value is adopted by the Committee, as well.

Calculations of the energy released due to weight loss were, in all reports except the (oldest) HCNL report from 2001, based on an average weight loss of 0.8 kg per month during the first six months *postpartum* in well-nourished lactating women.[64,76] The Committee believes that this value is plausible, because the total postnatal weight loss of 4.8 kg (0.8 kg/month * 6 months) largely corresponds to the average amount of protein (686 g) and fat (4.3 kg) that is deposited in body tissue during pregnancy in well-nourished women with optimal gestational weight gain.[64] There is international consensus that the energy density of body tissue is 6.5 kcal/g, as this value is applied in all of the reports evaluated. Therefore, the Committee adopts the approach and underlying data used by EFSA.

In the Committee's view, the average PAL value during lactation should be used for calculating the total daily energy requirement of lactating women (on a group level) and not the PAL value that applied before pregnancy. This is different than for pregnant women, for whom the pre-pregnant PAL value can be used. This is a consequence of the way the additional requirement is derived. For pregnant women, changes in TEE were considered. TEE includes energy expended on physical activity. For lactating women, changes in REE were considered. REE does not include energy expenditure on physical activity.

The average requirements apply to well-nourished lactating women that are exclusively breastfeeding their baby in the first six months *postpartum* and experienced an average gestational weight gain. Undernourished lactating women generally lose less weight (0.1 instead of 0.8 kg/mo) and thus a negligible amount of energy (22 kcal/d) is released from maternal tissue stores.[64] Consequently, their additional energy requirement is higher than that of well-nourished women. Women who are partially breastfeeding may also have a different (i.e. lower) additional energy requirement, depending on the infant's energy intake from complementary foods.

#### 4.5.3 Summary

The Committee adopts EFSA's approach for the derivation of additional energy requirements for lactating women, with the exception that it does not apply an energy conversion factor to account for the energetic costs of milk synthesis. The additional requirement for women that exclusively breastfeed their child in the first six months *postpartum* is calculated as the energy content of the breast milk minus the energy released from maternal tissue stores. The Committee's derivation of the additional requirement and the final value for lactating women from the Netherlands are shown in **Table 10**.

**Table 9** Overview of the criteria on which the additional energy requirement for lactating women (who are exclusively breastfeeding) is based by EFSA and other national and international organisations

| Organisation | Age of baby (mo) | Additional requirement (kcal/d) | Method of derivation of additional requirement[a] | Energy requirement for milk production (kcal/d) | Method of derivation of energy requirement for milk production | Energy released from tissues due to weight loss (kcal/d) | Method of derivation of energy released from tissues |
|---|---|---|---|---|---|---|---|
| EFSA, 2013[6] | 0 to <6 | 500 | Additional requirement = energy required for milk production – energy released from tissue due to weight loss | 670 | The average amount of energy required for milk production was calculated based on the mean milk production measured in well-nourished women with healthy babies (807 g/d),[8,80] the energy density of milk (0.67 kcal/g)[64] and the energetic efficiency (80%).[64] | 170 | The average amount of energy released due to weight loss was calculated based on the average weight loss in well-nourished women during the first 6 mo pp (0.8 kg/mo)[76] and the energy density of body tissue (6.5 kcal/g).[64] |
| | ≥6 | N/A | N/A. Volumes of breast milk secreted are highly variable and depend on an infant's energy intake from complementary foods. | N/A | N/A | N/A | N/A |
| HCNL, 2001[7] | 0 to <6 | 500[b] | Additional requirement = energy required for milk production – energy released from tissue due to weight loss | 650[b] | The average amount of energy required for milk production was calculated based on mean milk production when exclusively breastfeeding (800 mL/d), the energy density of milk (0.65 kcal/mL)[54,66] and the energetic efficiency (80%).[66] | 150[b] | The average amount of energy released due to weight loss (19 MJ/mo) was based on the average weight loss in well-nourished women during the first 6 mo pp (0.5 kg/mo)[66].[66] |
| FAO/WHO/UNU, 2004[8] | 0 to <6 | 505 | Additional requirement = energy required for milk production – energy released from tissue due to weight loss | 675 | The average amount of energy required for milk production was calculated based on the mean milk production measured in well-nourished women with healthy babies (807 g/d)[80], the energy density of milk (0.67 kcal/g)[64] and the energetic efficiency (80%).[64] | 170 | The average amount of energy released due to weight loss was calculated based on the average weight loss in well-nourished women during the first 6 mo pp (0.8 kg/mo)[76] and the energy density of body tissue (6.5 kcal/g).[64,76] |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | ≥6 | N/A | NA. Volumes of breast milk secreted are highly variable and depend on an infant's energy intake from complementary foods. | N/A | N/A | N/A | N/A |
| IoM, 2005[9] | 0 to <6 | 330 | Additional requirement[c] = milk energy output – energy released from tissue due to weight loss | 500<br><br>(Value was rounded.) | The average amount of energy required for milk production was calculated based on the mean milk production measured in American women with term infants (780 mL/d)[81,82] and the energy density of milk (0.67 kcal/g). | 170 | The average amount of energy released due to weight loss was calculated based on the average weight loss in well-nourished women during the first 6 mo pp (0.8 kg/mo)[76] and the energy density of body tissue (6.5 kcal/g).[76] |
| | 7 to <12 | 400 | Additional requirement[c] = milk energy output – energy released from tissue due to weight loss | 400<br><br>(Value was rounded.) | Average amount of energy required for milk production was calculated based on the mean milk production measured in American women with term infants (600 mL/d)[83] and the energy density of milk (0.67 kcal/g). | 0 | Body weight is assumed to be stable, thus no energy is released from the body tissues. |
| NCM, 2014[10] | 0 to ≤2<br>3 to <6<br>6 to <9<br>9 to <12 | 425[d]<br>490[d]<br>670[d]<br>755[d] | Additional requirement = energy required for milk production – energy released from tissue due to weight loss<br><br>The costs of milk production can be covered by an increase in energy intake from food or by mobilised body fat during the first six months of lactation. | 595[b,e]<br>660[b,e]<br>670[b,e]<br>755[b,e] | Average amounts of energy required for milk production per age group were obtained from Butte & King (2005)[64] and based on the mean milk production measured in well-nourished women with healthy babies (749 g/d),the energy density of milk (0.67 kcal/g)[64] and the energetic efficiency (80%). | 0 to <6: 170<br><br>≥6 mo: 0 | The average amount of energy released due to weight loss was calculated based on the average weight loss in well-nourished women during the first 6 mo pp (0.8 kg/mo)[76] and the energy density of body tissue (6.5 kcal/g).[64] |
| DACH, 2015[11,12] | 0 to <6 | ~500[f] | Additional requirement = energy required for milk production – energy | 656d[f] | Average amount of energy required for milk production was calculated based on a measured mean milk production of 750 | 170 | The average amount of energy released due to weight loss was calculated based on the average weight loss in well-nourished women |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | released from tissue due to weight loss | | mL/d[84] (containing ~500 kcal/d[85,86]) and the energetic efficiency (80%).[64] | | during the first 6 mo pp (0.8 kg/mo)[76] and the energy density of body tissue (6.5 kcal/g).[64] |
| | ≥6 | N/A | N/A. Volumes of breast milk secreted are highly variable and depend on an infant's energy intake from complementary foods. | N/A | N/A | N/A | N/A |
| SACN, 2011[13] | 0-6 | 330 | Additional requirement = milk energy output – energy released from tissue due to weight loss | 500 | The average amount of energy required for milk production was calculated based on the mean milk production measured in American women with term infants (780 mL/d)[81,82] and the energy density of milk (0.67 kcal/g).[64] | 170 | The average amount of energy released due to weight loss was calculated based on the average weight loss in well-nourished women during the first 6 mo pp (0.8 kg/mo)[76] and the energy density of body tissue (6.5 kcal/g).[64] |

AR: average requirement; BEE: basal energy expenditure; d: day; DACH: German-speaking countries Germany (Deutschland), Austria and Switzerland (Confoederatio Helvetica); EFSA: European Food Safety Authority; FAO/WHO/UNU: Food and Agriculture Organisation of the United Nations/World Health Organisation/United Nations University; g: gram; HCNL: Health Council of the Netherlands; IoM: Institute of Medicine; NCM: Nordic Council of Ministers; PAL: physical activity level; pp: postpartum; REE: resting energy expenditure; SACN: Scientific Advisory Committee on Nutrition; TEE: total energy expenditure; y: years

[a] Generally, organisations calculate an 'additional requirement' for lactating women, which is the extra amount of energy needed during lactation. This additional requirement should be added to the AR for non-pregnant, non-lactating women (assuming that the PAL during lactation is equal to the pre-pregnancy PAL).

[b] Values in MJ/d are converted to kcal/d as follows: kcal/d = MJ/d * 1000 / 4.184. One month is considered equal to 30.42 days (365 days / 12 months per year).

[c] IoM likely did not apply an energy conversion factor since it decided, based on its DLW data, that TEE measured before pregnancy and lactation was similar to TEE measured during lactation. The synthetic cost of milk production is already accounted for in the estimate of TEE.

[d] Those values are not provided in NCM report, but they are calculated based on the reported energy requirement for milk production and energy released from tissue due to weight loss.

[e] These values apply to exclusively breastfeeding women. NCM recommends that Scandinavian women exclusively breastfeed during the first six months *postpartum* and then to do so partially until the child is at least one year old.

[f] DACH reported values of 656 kcal/d for the energy required for milk production and ~500 kcal/d for the additional requirement. However, based on their reported values for the energy content of milk (500 kcal/d) and the energetic efficiency (80%), the energy required for milk production should be 625 kcal/d. Consequently, the additional requirement would be ~450 kcal/d.

**Table 10** Derivation of the additional energy requirement for lactating women from the Netherlands (who were exclusively breastfeeding) for the first six months postpartum[a]

| Age of baby (mo) | Average breast milk production (g/d)[b] | Energy content of breast milk (kcal/d)[c] | Average weight loss (g/d)[d] | Energy released from tissue due to weight loss (kcal/d)[e] | Additional requirement (kcal/d) |
|---|---|---|---|---|---|
| 0 to <6 | 807 | 541 | 26.3 | 171 | 370 |

g/d: grams per day; kcal/d: kilocalories per day; mo: months

[a] Additional requirement = energy content of breast milk – energy released from tissue due to weight loss.

[b] Average measured mean milk production in well-nourished women with healthy babies.[8,80]

[c] Energy content of breast milk = breast milk production * energy density of breast milk (0.67 kcal/g).[64]

[d] Average weight loss observed in well-nourished women during the first 6 months postpartum (0.8 kg/mo).[76] 0.8 kg/mo equals to 26.3 g/d.

[e] Average amount of energy released due to weight loss = average weight loss * energy density of body tissue (6.5 kcal/g).[64]

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# Annex A
# Prediction equations for energy expenditure

## Adults

### *Prediction equations for basal or resting energy expenditure*

**Table A1** Prediction equations for basal energy expenditure in adults, developed by Henry (2005)[15] on the basis of direct and indirect calorimetry studies

| Age group | Equation for REE (kcal/d) for men[a] | Equation for REE (kcal/d) for women[a] |
|---|---|---|
| 18 to 30 y | 14.4*BW + 313*H + 113 | 10.4*BW + 615*H – 282 |
| 30 to 60 y | 11.4*BW + 541*H – 137 | 8.18*BW + 502*H – 11.6 |
| >60 y | 11.4*BW + 541*H – 256 | 8.52*BW + 421*H + 10.7 |

BW: body weight; H: height; kcal/d: kilocalories per day; REE: resting energy expenditure; y: years

[a] Body weight in kilograms and height in metres.

**Table A2** Prediction equations for resting energy expenditure in adults, developed by Schofield (1985)[30] on the basis of direct and indirect calorimetry studies

| Age group | Equation for REE (MJ/d) for men[a] | Equation for REE (MJ/d) for women[a] |
|---|---|---|
| 18 to 30 y | 0.063*BW – 0.042*H + 2.953 | 0.057*BW + 1.184*H + 0.411 |
| 30 to 60 y | 0.048*BW – 0.011*H + 3.67 | 0.034*BW + 0.006*H + 3.53 |
| >60 y | 0.038*BW + 4.068*H – 3.491 | 0.033*BW + 1.917*H + 0.074 |

BW: body weight; MJ/d: megajoules per day; H: height; REE: resting energy expenditure; y: years

[a] Body weight in kilograms and height in metres.

**Table A3** Prediction equation for resting energy expenditure in adults, developed by Müller et al. (2004)[31] on the basis of open circuit indirect calorimetry studies

| Age group | Equation for REE (MJ/d)[a] |
|---|---|
| 5 to 19 y | 0.047*BW + 1.009*S – 0.01452*A + 3.21 |

A: age; BW: body weight; H: height; MJ/d: megajoules per day; REE: resting energy expenditure; S: sex; y: years

[a] Body weight in kilograms and age in years. Sex: 0=women, 1=men.

### *Prediction equations for total energy expenditure*

**Table A4** Prediction equation for total energy expenditure in adults, developed by IoM (2005)[9] on the basis of doubly-labelled water studies

| Age group | Equation for TEE (kcal/d) for men[a,b] | Equation for TEE (kcal/d) for women[a,b] |
|---|---|---|
| ≥19 y | 662 – (9.53*A) + PA*(15.91*BW + 539.6*H) | 354 – (6.91*A) + PA*(9.36*BW + 726*H) |

A: age; BW: body weight; IoM: Institute of Medicine; kcal/d: kilocalories per day; PA: physical activity; PAL: physical activity level; TEE: total energy expenditure; y: years

[a] Body weight in kg, age in years, and height in m.

[b] PA=1.00 if PAL is ≥1.0 to < 1.4 (sedentary), PA=1.11 (men) or 1.12 (women) if PAL is ≥1.4 to <1.6 (low active), PA=1.25 (men) or 1.27 (women) if PAL is ≥1.6 <1.9 (active), and PA=1.48 (men) or 1.45 (women) if PAL is ≥1.9 <2.5 (very active).

## Infants and children

### *Prediction equations for basal or resting energy expenditure*

**Table A5** Prediction equations for basal energy expenditure in children, developed by Henry (2005)[15] on the basis of direct and indirect calorimetry studies

| Age group | Equation for REE (kcal/d) for boys[a a] | Equation for REE (kcal/d) for girls[a] |
|---|---|---|
| 0 to 3 y | 28.2*BW + 859*H – 371 | 30.4*BW + 703*H – 287 |
| 3 to 10 y | 15.1*BW + 74.2*H + 306 | 15.9*BW + 210*H + 349 |
| 10 to 18 y | 15.6*BW + 266*H + 299 | 9.40*BW + 249*H + 462 |

BW: body weight; d: day; H: height; REE: resting energy expenditure; y: year

[a] Body weight in kg and height in m.

**Table A6** Prediction equations for resting energy expenditure in children, developed by Schofield (1985)[30] on the basis of direct and indirect calorimetry studies

| Age group | Equation for REE (MJ/d) for boys[a] | Equation for REE (MJ/d) for girls[a] |
|---|---|---|
| 0 to 3 y | 0.0007*BW + 6.349*H - 2.584 | 0.068*BW + 4.281*H - 1.730 |
| 3 to 10 y | 0.082*BW + 0.545*H + 1.736 | 0.071*BW + 0.677*H + 1.553 |
| 10 to 18 y | 0.068*BW + 0.574*H + 2.157 | 0.035*BW + 1.948*H + 0.837 |

BW: body weight; H: height; MJ/d: megajoules per day; REE: resting energy expenditure; y: years

[a] Body weight in kilograms and height in metres.

**Table A7** Prediction equations for basal energy expenditure in (normal-weight) children, developed by IoM (2005)[9]

| Age group | Equation for BEE (kcal/d) for boys[a] | Equation for BEE (kcal/d) for girls[a] |
|---|---|---|
| 3 to <19 y | 68 – 43.3*A + 712*H + 19.2*BW | 189 – 17.6*A + 625*H + 7.9*BW |

A: age; BEE: basal energy expenditure; BW: body weight; H: height; kcal/d: IoM: Institute of Medicine; kilocalories per day; y: year

[a] Age in years, body weight in kilograms and height in metres.

### *Prediction equations for total energy expenditure*

**Table A8** Prediction equations for total energy expenditure in infants aged 0 through 2 years, developed by Butte (2005)[46] on the basis of doubly-labelled water studies

| Mode of feeding | Equation for TEE (kcal/d)[a] |
|---|---|
| Breast-fed | 92.8*BW – 152 |
| Formula-fed | 82.6*BW – 29.0 |
| Mixed-fed (all infants) | 88.6*BW – 99.4 |

BW: body weight; kcal/d: kilocalories per day; TEE: total energy expenditure; y: year.

[a] Body weight in kilograms.

**Table A9** Prediction equation for total energy expenditure in infants, developed by IoM (2005)[9] on the basis of doubly-labelled water studies

| Age group | Equation for TEE (kcal/d)[a] |
|---|---|
| 0 to <3 y (0 to <36 mo) | 89*BW – 100 |

BW: body weight; kcal/d: kilocalories per day; mo: months; TEE: total energy expenditure; y: year.

[a] Body weight in kilograms.

**Table A10** Prediction equation for total energy expenditure in (normal-weight) children, developed by Torun (2005)[58] on the basis of doubly-labelled water and heart rate monitoring studies

| Age group | Equation for TEE (kcal/d) for boys[a] | Equation for TEE (kcal/d) for girls[a] |
|---|---|---|
| 1 to ≤18 y | $310.2 + 63.3*BW – 0.263*BW^2$ | $263.4 + 65.3*BW – 0.454*BW^2$ |

Note that this is a quadratic regression model.

BW: body weight; kcal/d: kilocalories per day; TEE: total energy expenditure; y: year.

[a] Body weight in kilograms.

**Table A11** Prediction equations for total energy expenditure in (normal-weight) children, developed by IoM (2005)[9] on the basis of doubly-labelled water studies

| Age group | Equation for TEE (kcal/d) for boys[a,b] | Equation for TEE (kcal/d) for girls[a,b] |
|---|---|---|
| 3 to <19 y | 88.5 – 61.9*A + PA*(26.7*BW + 903*H) | 135.3 – 30.8*A + PA*(10.0*BW + 934*H) |

A: age; BW: body weight; kcal/d: kilocalories per day; H: height; PA: physical activity; PAL: physical activity level; TEE: total energy expenditure; y: years

[a] Age in years, body weight in kilograms and height in metres.

[b] PA=1.0 if PAL is ≥1.0 to <1.4 (sedentary), PA=1.13 (boys) or 1.16 (girls) if PAL is ≥1.4 to <1.6 (low active), PA=1.26 (boys) or 1.31 (girls) if PAL is ≥1.6 to <1.9 (active), PA=1.42 (boys) or 1.56 (girls) if PAL is ≥1.9 to <2.5 (very active).

# Annex B
# Background information on prediction equations for energy expenditure

## Prediction equations for basal or resting energy expenditure

### *Adults and children*

**Table B1** Background information on prediction equations for resting energy expenditure in adults and children used in various national and international reports

| Author(s) | Separate equations for groups according to | Factor(s) in equation | Characteristics of databases in which the equations were developed | Report in which the equations were used for adults[a] | Report in which the equations were used for children[b] |
|---|---|---|---|---|---|
| Henry, 2005[15] | Sex, age | Body weight, height | n=10496 from 166 published studies (men: 0-3 y: n=246, 3-10 y: n=289, 10-18 y: n=863, 18-30 y: n=2816, 30-60 y: n=1006, 60+: n=533; women: 0-3 y: n=201, 3-10 y: n=403, 10-18 y: n=1063, 18-30 y: n=1655, 30-60 y: n=1023, 60+: n=324), 45% female; 38% subjects from tropical countries.<br><br>Henry did not include the data from very active Italian subjects who had BEE measured with a closed-circuit indirect calorimetry method.[c] | EFSA (2013), NCM (2014), SACN (2011) | EFSA (2013), DACH (2015), NCM (2014), SACN (2011) |
| Müller et al., 2004[31] | BMI | Sex, age, body weight, height | n= 2528 (development in subpopulation 1 (n=1046) and cross-validation in subpopulation 2 (n=1059)); 5-91 y (men: 5-11 y: n=99, 12-17 y: n=28, 18-29 y: n=254, 30-39 y: n=158, 40-49 y: n=117, 50-59 y: n=100, 60-69 y: n=127, 70-79: n=34, ≥80 y: n=8; women: 5-11 y: n=89, 12-17 y: n=27, 18-29 y: n=398, 30-39 y: n=145, 40-49 y: n=182, 50-59 y: n=213, 60-69 y: n=258, 70-79: n=88, ≥80 y: n=23 ); 60% female; healthy Germans.<br><br>REE was measured with open circuit indirect calorimetry methods. | DACH (2015) | None. |
| Schofield, 1995[30] | Sex, age | Body weight, height | n=7173 from 114 published studies (men: 0-3 y: n=162, 3-10 y: n=338, 10-18 y: n=734, 18-30 y: n=2879, 30-60 y: n=646, 60+: n=50; women: 0-3 y: n=137, 3-10 y: n=413, 10-18 y: n=575, 18-30 y: n=829, 30-60 y: n=372, 60+: n=38); 33% female, mostly European and North American subjects (47% Italians; 57% of males and 27% of females), 13% subjects from tropical countries and 7% Indians.<br><br>Schofield included multiple studies among very active Italian subjects, in whom a high BEE was measured with a closed-circuit indirect calorimetry method.[c] | HCNL (2001), FAO/WHO/UNU (2004) | HCNL (2001) |

BEE: basal energy expenditure; BMI: body mass index; BMR: basal metabolic rate; DACH: German-speaking countries Germany (Deutschland), Austria and Switzerland (Confoederatio Helvetica); EFSA: European Food Safety Authority; FAO/WHO/UNU: Food and Agriculture Organisation of the United Nations/World Health Organisation/United Nations University; HCNL: Health Council of the Netherlands; IoM: Institute of Medicine; NCM: Nordic Council of Ministers; REE: resting energy expenditure; SACN: Scientific Advisory Committee on Nutrition; y: years

[a] IoM did not predict REE in adults, but TEE, and is therefore not listed in the table.

[b] FAO/WHO/UNU and IoM did not predict REE in children, but TEE, and are therefore not listed in the table.

[b] Schofield (1985)[30] included multiple studies performed in the 1930s and 1940s on physically very active (Italian) men with relatively high BMR values. Closed-circuit indirect calorimetry was used in most studies to estimate BMR, which has been queried as it might overestimate oxygen consumption and thus energy expenditure. Questions have also been raised about the universal applicability of the Schofield equations as the majority of studies in Schofield's database were performed in European and North American subjects.

## Prediction equations for total energy expenditure

### *Adults*

**Table B2** Background information on prediction equations for total energy expenditure in adults used in IoM's report (2005)

| Author(s) | Separate equations for groups according to | Factor(s) in equation | Characteristics of databases in which the equations were developed | Report in which the equations were used[a] |
|---|---|---|---|---|
| IoM, 2005[9] | Sex | Age, body weight, height, physical activity | n=407; 58% female; majority of studies conducted in the USA or the Netherlands with the remainder in the UK, Australia or Sweden.<br><br>Individual DLW data (TEE measured) and ancillary data (e.g. age, sex, weight, BEE measured or predicted) of infants, children and adults were collected from over 20 investigators identified in the literature.[b]<br><br>Inclusion criteria: healthy, free-living, stable body weight, measured height and boy weight, and with BMI between 18.5 and 25 kg/m$^2$. Exclusion criteria: undernutrition, acute and chronic diseases, underfeeding and overfeeding protocols, lifestyles involving uncommonly high levels of physical activity (e.g., elite athletes, astronauts, military trainees, and those with a PAL value >2.5.<br><br>TEE was measured with the doubly-labelled water method. | IoM (2005) |

BEE: basal energy expenditure; BMI: body mass index; IoM: Institute of Medicine; kg/m$^2$: kilograms per meter squared; PAL: physical activity level; REE: resting energy expenditure; TEE: total energy expenditure; UK: United Kingdom; USA: United States of America

[a] The other institutes did not predict TEE in adults, but REE, and are therefore not listed in the table.

[b] Remark taken from the IoM report: "The available DLW data are not from randomly selected individuals and they do not constitute a sample representative of the population of the United States and Canada. However, the measurements were obtained in men, women, and children whose ages, body weights, heights, and physical activities varied over wide ranges. At the present time, a few age groups are underrepresented and interpolations had to be performed in these cases."

### *Infants*

**Table B3** Background information on prediction equations for total energy expenditure in infants used in various national and international reports

| Author(s) | Separate equations for groups according to | Factor(s) in equation | Characteristics of databases in which the equations were developed | Report in which the equations were used[a] |
|---|---|---|---|---|
| Butte (2005)[46] | Mode of feeding (breast-fed, formula-fed, mixed-fed/ unknown[b]) | Body weight | 76 healthy, normally-growing full-term infants with adequate body mass that were initially breast-fed (n=40) or formula-fed (n=36), respectively, for 4 months after birth were longitudinally studied for the first 2 years of life (months 3, 6, 9, 12, 18 and 24)[47]; no. of observations = 320; USA<br><br>TEE was measured using the doubly-labelled water method. | *All 3 equations:* FAO/WHO/UNU (2004), SACN (2011)<br><br>*Equation for breast-fed infants:* EFSA (2013), DACH (2015) |
| IoM (2005)[9] | NA | Body weight | n=320<br><br>Individual DLW data (measured TEE) and ancillary data (e.g. age, sex, weight, measured or predicted BEE) of infants, children and adults were collected from over 20 investigators identified in the literature.[c]<br><br>Inclusion criteria: healthy, free-living, stable body weight, measured height and body weight, and within the 3rd to 97th percentile for weight-for-height. Exclusion criteria: undernutrition, acute and chronic diseases, underfeeding and overfeeding protocols, lifestyles involving unusually high levels of physical activity (e.g., elite athletes, astronauts, military trainees, and those with a PAL value >2.5.<br><br>TEE was measured with the doubly-labelled water method. | IoM (2005) |

BEE: basal energy expenditure; DACH: German-speaking countries Germany (Deutschland), Austria and Switzerland (Confoederatio Helvetica); EFSA: European Food Safety Authority; FAO/WHO/UNU: Food and Agriculture Organisation of the United Nations/World Health Organisation/United Nations University; HCNL: Health Council of the Netherlands; IoM: Institute of Medicine; NCM: Nordic Council of Ministers; PAL: physical activity level; REE: resting energy expenditure; SACN: Scientific Advisory Committee on Nutrition; TEE: total energy expenditure; USA: United States of America

[a] HCNL did not predict TEE in infants and is therefore not listed in the table. The equation used by NCM is unknown.

[b] The prediction equation for all infants (i.e. infants fed with both breast milk and formula, or whose mode of feeding was unknown) was based on both breast-fed and formula-fed infants (n=76).

[c] Remark taken from IoM report: “The available DLW data are not from randomly selected individuals and they do not constitute a sample representative of the population of the United States and Canada. However, the measurements were obtained in men, women, and children whose ages, body weights, heights, and physical activities varied over wide ranges. At the present time, a few age groups are underrepresented and interpolations had to be performed in these cases.”

## *Children*

**Table B4** Background information on prediction equations for total energy expenditure in children used in the reports of FAO/WHO/UNU (2004) and IoM (2005)

| Author(s) | Separate equations for groups according to | Factor(s) in equation | Characteristics of databases in which the equations were developed | Report in which the equations were used[a] |
|---|---|---|---|---|
| Torun, 2005[58] | Sex | Body weight | n=801 boys and 808 girls aged 1 to <18 y, from 54 studies on boys and 52 studies on girls; most (56% of boys and 68% of the girls) were from the UK or the USA, 18% (boys and girls) were from Canada, Denmark, Sweden or the Netherlands and the remainder were from Brazil, Chile, Colombia, Guatemala or Mexico.<br><br>TEE was measured using the doubly-labelled water method (in 483 boys and 646 girls) or heart rate monitoring (in 318 boys and 162 girls). | FAO/WHO/UNU (2004) |
| IoM, 2005[9] | Sex | Age, body weight, height, physical activity | n=525; 68% female; all studies conducted in the USA<br><br>Individual DLW data (TEE measured) and ancillary data (e.g. age, sex, weight, BEE measured or predicted) of infants, children and adults were collected from over 20 investigators identified in the literature.[b]<br><br>Inclusion criteria: healthy, free-living, stable body weight, measured height and boy weight, and within the 5$^{th}$ to 85$^{th}$ percentile for BMI. Exclusion criteria: undernutrition, acute and chronic diseases, underfeeding and overfeeding protocols, lifestyles involving unusually high levels of physical activity (e.g., elite athletes, astronauts, military trainees, and those with a PAL value >2.5.<br><br>TEE was measured using the doubly-labelled water method. | IoM (2005) |

BEE: basal energy expenditure; BMI: body mass index; DACH: German-speaking countries Germany (Deutschland), Austria and Switzerland (Confoederatio Helvetica); DLW: doubly-labelled water; EFSA: European Food Safety Authority; FAO/WHO/UNU: Food and Agriculture Organisation of the United Nations/World Health Organisation/United Nations University; HCNL: Health Council of the Netherlands; IoM: Institute of Medicine; NCM: Nordic Council of Ministers; PAL: physical activity level; REE: resting energy expenditure; SACN: Scientific Advisory Committee on Nutrition; TEE: total energy expenditure; UK: United Kingdom; USA: United States of America; y: years

[a] EFSA, DACH, NCM, SACN and HCNL did not predict TEE in children, but REE, and are therefore not listed in the table.

[b] Remark taken from IoM report: "The available DLW data are not from randomly selected individuals and they do not constitute a sample representative of the population of the United States and Canada. However, the measurements were obtained in men, women, and children whose ages, body weights, heights, and physical activities varied over wide ranges. At the present time, a few age groups are underrepresented and interpolations had to be performed in these cases."

# Annex C
# Datasets for derivation of PAL values

### *Adults*

**Table C1** Databases from which PAL values for adults were derived in various national and international reports

| Author(s) | Characteristics of database | Characteristics of subjects | Results | Report for which database was used[a] |
|---|---|---|---|---|
| Black et al., 1996[32] | Database of DLW data available up to mid-1994 (published and unpublished individual data); 74 studies | n=574 healthy, free-living, normally active subjects (163 children aged 1-17 y and 411 adults aged ≥18 y) whose BEE, REE or SEE was also measured[b]; 56% female<br><br>n=154 subjects with or under special conditions[c]<br><br>Excluded: subjects from developing countries, pregnant or lactating subjects | 1-6 y: ♂ n=29, 1.64 ± 0.39, ♀ n=21, 1.57 ± 0.30<br>7-12 y: ♂ n=32, 1.74 ± 0.22, ♀ n=24, 1.68 ± 0.16<br>13-17 y: ♂ n=31, 1.75 ± 0.19, ♀ n=26, 1.73 ± 0.24<br>18-29 y: ♂ n=56, 1.85 ± 0.33, ♀ n=89, 1.70 ± 0.28<br>30-39 y: ♂ n=36, 1.77 ± 0.31, ♀ n=76, 1.68 ± 0.25<br>40-64 y: ♂ n=15, 1.64 ± 0.17, ♀ n=47, 1.69 ± 0.23<br>65-74 y: ♂ n=22, 1.61 ± 0.28, ♀ n=24, 1.62 ± 0.28<br>≥75 y: ♂ n=34, 1.54 ± 0.24, ♀ n=12, 1.48 ± 0.23<br><br>Model value observed in adults aged 18-64 y (n=319): PAL = 1.6<br><br>Lower limit: PAL = 1.21<br>Based on mean PAL values observed in studies of totally sedentary subjects including non-ambulatory demented elderly, non-ambulatory adolescents in wheelchairs and subjects included in “no exercise” calorimeter studies; n=39<br><br>Upper limit (sustainable): PAL = 2.5<br>Based on mean PAL values observed in studies in soldiers and athletes in routine training (sustainable) versus studies in athletes and explorers, i.e. cyclists in Tour the France or Nordic skiers, or during rigorous training (not sustainable; PAL 2.8-4.7); n=115 | EFSA (2013), HCNL (2001), FAO/WHO/UNU (2004), DACH (2015), NCM (2014) |

| | | | | |
|---|---|---|---|---|
| Subar et al., 2003[34]; Tooze et al., 2007[35] (OPEN dataset) | DLW study | n=451 (245 men and 206 women) healthy subjects aged 40-69 y, recruited from a random sample of 5000 households in the Washington DC metropolitan area, USA (urban population); ~85% were white and the remainder mainly black or Asian; BMI[d]: 30% normal, 41% overweight, 29% obese; mean body weight: females 73 kg, males 88 kg; mean height: females 1.63 m, males 1.77 m. | Observed distribution of PAL values:<br>Minimum: 1.01<br>10th centile: 1.40<br>25th centile: 1.49<br>50th centile: 1.61<br>75th centile: 1.77<br>90th centile: 1.92<br>Maximum: 2.61 | SACN (2011), NCM (2014) |
| Moshfegh et al., 2008[33] (Beltsville dataset) | DLW study | n=478 healthy subjects aged 30-69 y, recruited from the Washington DC metropolitan area, USA; subjects were predominately non-Hispanic and white and were distributed evenly by sex and approximately by age; BMI[d]: ~42% normal, ~63% overweight, 21% obese; body weight and height were not reported. | Observed distribution of PAL values:<br>Minimum: 1.01<br>10th centile: 1.32<br>25th centile: 1.46<br>50th centile: 1.62<br>75th centile: 1.78<br>90th centile: 1.96<br>Maximum: 2.34 | SACN (2011), NCM (2014) |

BEE: basal energy expenditure; BMI: body mass index; DLW: doubly-labelled water; DACH: German-speaking countries Germany (Deutschland), Austria and Switzerland (Confoederatio Helvetica); EFSA: European Food Safety Authority; FAO/WHO/UNU: Food and Agriculture Organisation of the United Nations/World Health Organisation/United Nations University; HCNL: Health Council of the Netherlands; NCM: Nordic Council of Ministers; PAL: physical activity level; REE: resting energy expenditure; SACN: Scientific Advisory Committee on Nutrition; SEE: sleeping energy expenditure; TEE: total energy expenditure; USA: United States of America; y: years

[a] IoM used its own database to define PAL values and is therefore not listed in the table.

[b] The total database included 1614 DLW measurements in 1156 subjects. Subjects were either healthy, free-living subjects aged 2-95 y (n=876); healthy subjects with particular activity patterns (e.g. soldiers, athletes; n=293); or subjects participating in special studies (e.g. overfeeding and underfeeding). For the main analysis, the data was used from 574 of the 876 free-living subjects whose BEE, REE or SEE was also measured. If BEE was not measured, it was calculated as SEE * 1.05.

[c] For the subjects with special conditions or studies conducted under special conditions, either BEE was measured or it was predicted using the Schofield equations.

[d] BMI classification – normal: 18.5-24.9 kg/m$^2$, overweight: 25-29.9 kg/m$^2$, obese: ≥30 kg/m$^2$.

**Table C2** Databases of PAL values of Dutch adults

| Author(s) | Characteristics of database | Characteristics of subjects | Results |
|---|---|---|---|
| Speakman & Westerterp 2010[44] | DLW study (and BEE measured using respirometry); measurements were performed between 1983 and 2006 | n=529 (289 men and 240 women) healthy subjects aged 18-96 y from the Netherlands; individuals undergoing interventions involving energy intake, undergoing physical activity and those who were pregnant, lactating or diseased were excluded. | 18-29 y: ♂ n=62, 1.88 ± 0.24, ♀ n=83, 1.75 ± 0.20<br>30-39 y: ♂ n=71, 1.79 ± 0.25, ♀ n=51, 1.68 ± 0.19<br>40-49 y: ♂ n=58, 1.88 ± 0.25, ♀ n=32, 1.71 ± 0.16<br>50-59 y: ♂ n=23, 1.88 ± 0.34, ♀ n=19, 1.65 ± 0.11<br>60-69 y: ♂ n=23, 1.69 ± 0.30, ♀ n=24, 1.67 ± 0.24<br>70-79 y: ♂ n=39, 1.57 ± 0.23, ♀ n=6, 1.63 ± 0.21<br>80-89 y: ♂ n=39, 1.37 ± 0.14, ♀ n=9, 1.23 ± 0.08<br>90-99 y: ♂ n=7, 1.36 ± 0.17, ♀ n=10, 1.36 ± 0.13 |
| Pannemans et al. 1995[45] | DLW study (and BEE measured using a ventilated-hood system) | n=26 older persons in good health from the Netherlands; n=16 men with a mean age of 71 ± 5 y and BMI of 25 ± 3 kg/m$^2$; n=10 women with a mean age of 68 ± 4 y and BMI of 26 ± 3 kg/m$^2$. | Men: 1.52 ± 0.20 (range: 1.27-2.05)<br>Women: 1.66 ± 0.20 (range: 1.34-2.00) |

BMI: body mass index; DLW: doubly-labelled water; PAL: physical activity level; y: years

## *Children*

**Table C3** Databases from which PAL values for children were derived in various national and international reports

| Author(s) | Characteristics of database | Characteristics of subjects | Results | Report for which database was used[a] |
|---|---|---|---|---|
| Torun et al., 1996[59] | Review of studies using the DLW method or heart rate monitoring techniques | *DLW data:*<br>n=190 well-nourished boys and n=206 well-nourished girls aged 1 to <19 y, from 8 studies; studies were performed in the USA, UK or the Netherlands.<br><br>*Heart rate monitoring data:*<br>n=373 boys and n=318 girls aged 2 to <16 y, from 13 studies; studies were conducted in the UK, the Netherlands, Canada, Columbia or Guatemala. | *DLW data:*<br>Mean PAL values:<br>1-5 y: ♂ 1.46, ♀ 1.44<br>6-13 y: ♂ 1.79, ♀ 1.80<br>≥14 y: ♂ 1.84, ♀ 1.69<br><br>*Heart rate monitoring data:*<br>Weighted mean PAL values for children with adequate weight and height:<br>2-3 y: ♂ NR, ♀ NR<br>6-13 y: ♂ 1.65, ♀ 1.60<br>≥14 y: ♂ 1.89, ♀ 1.63 | HCNL (2001): only DLW data |

| | | | | |
|---|---|---|---|---|
| Torun, 2005[58] | Review of studies using the DLW method or heart rate monitoring techniques | n=801 boys and 808 girls aged 1 to <18 y, from 54 studies on boys and 52 studies on girls; most (56% of boys and 68% of the girls) were from the UK or the USA, 18% (boys and girls) were from Canada, Denmark, Sweden or the Netherlands and the remainder were from Brazil, Chile, Colombia, Guatemala or Mexico.<br><br>TEE was measured with the doubly-labelled water method (in 483 boys and 646 girls) or heart rate monitoring (in 318 boys and 162 girls). BEE was estimated with the Schofield equations. | 1-2 y: ♂ 1.43, ♀ 1.42<br>2-3 y: ♂ 1.45, ♀ 1.42<br>3-4 y: ♂ 1.44, ♀ 1.44<br>4-5 y: ♂ 1.49, ♀ 1.49<br>5-6 y: ♂ 1.53, ♀ 1.53<br>6-7 y: ♂ 1.57, ♀ 1.56<br>7-8 y: ♂ 1.60, ♀ 1.60<br>8-9 y: ♂ 1.63, ♀ 1.63<br>9-10 y: ♂ 1.66, ♀ 1.66<br>10-11 y: ♂ 1.71, ♀ 1.71<br>11-12 y: ♂ 1.75, ♀ 1.74<br>12-13 y: ♂ 1.79, ♀ 1.76<br>13-14 y: ♂ 1.82, ♀ 1.76<br>14-15 y: ♂ 1.84, ♀ 1.75<br>15-16 y: ♂ 1.84, ♀ 1.73<br>16-17 y: ♂ 1.84, ♀ 1.73<br>17-18 y: ♂ 1.83, ♀ 1.72 | FAO/WHO/UNU (2004) |
| SACN children's dataset[13] | Database compiled using DLW studies published up to 2006, including all DLW studies put together by Torun (2005)[58] | 170 data points (study means) representing 3502 individual measurements performed on well-nourished children aged >1 up to and including 18 y; 59% female; studies were mainly conducted in the UK or USA, single studies from Canada, Denmark, Sweden or the Netherlands were included and four studies were from Brazil, Chile, Guatemala or Mexico. | Observed distribution of PAL values:<br>1-3 y: n=242 from 14 studies:<br>Minimum: 1.26<br>25$^{th}$ centile: 1.35<br>50$^{th}$ centile: 1.39<br>75$^{th}$ centile: 1.43<br>Maximum: 1.46<br>4-9 y: n=1443 from 85 studies:<br>Minimum: 1.21<br>25$^{th}$ centile: 1.42<br>50$^{th}$ centile: 1.57<br>75$^{th}$ centile: 1.69<br>Maximum: 1.98<br>10-18 y: n=1817 from 71 studies:<br>Minimum: 1.42<br>25$^{th}$ percentile: 1.66<br>50$^{th}$ percentile: 1.73<br>75$^{th}$ percentile: 1.85<br>Maximum: 2.19 | EFSA (2013), SACN (2011), NCM (2014) |

DLW: doubly-labelled water; DACH: German-speaking countries Germany (Deutschland), Austria and Switzerland (Confoederatio Helvetica); EFSA: European Food Safety Authority; FAO/WHO/UNU: Food and Agriculture Organisation of the United Nations/World Health Organisation/United Nations University; HCNL: Health Council of the Netherlands; NCM: Nordic Council of Ministers; PAL: physical activity level; SACN: Scientific Advisory Committee on Nutrition; y: years

[a] DACH did not make clear on which database it based its PAL values. IoM used its own database to define PAL values. Therefore, those organisations are not listed in the table.

# Annex D
# Estimated REE based on various prediction equations

**Table D1** Predicted resting energy expenditure for various sex- and age-groups of adults, based on the equations developed by Henry (2005),[15] Schofield (1985)[30] and Müller (2004),[31] and by application of Dutch reference values for body weight and height

| Sex | Age group | Dutch reference weight (kg) | Dutch reference height (cm) | REE predicted with equations developed by Henry (kcal/d)[a] | REE predicted with equations developed by Schofield (kcal/d)[a] | REE predicted with equations developed by Müller (kcal/d)[a] | Difference in REE: Henry versus Schofield (kcal/d) | Difference in REE: Henry versus Müller (kcal/d) | Difference in REE: Schofield versus Müller (kcal/d) |
|---|---|---|---|---|---|---|---|---|---|
| Men | 18-29 y | 75.6 | 185.0 | 1776 | 1826 | 1774 | -49 | 2 | 51 |
| Men | 30-39 y | 73.1 | 182.3 | 1679 | 1711 | 1708 | -32 | -29 | 3 |
| Men | 40-49 y | 73.8 | 183.2 | 1692 | 1719 | 1681 | -27 | 11 | 38 |
| Men | 50-59 y | 75.4 | 181.1 | 1699 | 1737 | 1664 | -39 | 34 | 73 |
| Men | 60-69 y | 72.7 | 177.8 | 1535 | 1555 | 1599 | -19 | -64 | -45 |
| Men | 70-79 y | 73.6 | 175.1 | 1530 | 1536 | 1575 | -5 | -44 | -39 |
| Women | 18-29 y | 64.6 | 171.0 | 1437 | 1462 | 1410 | -25 | 27 | 53 |
| Women | 30-39 y | 63.1 | 169.3 | 1354 | 1359 | 1355 | -5 | -1 | 4 |
| Women | 40-49 y | 62.8 | 169.0 | 1350 | 1356 | 1316 | -6 | 33 | 40 |
| Women | 50-59 y | 63.8 | 166.5 | 1346 | 1365 | 1293 | -19 | 53 | 72 |
| Women | 60-69 y | 62.9 | 165.4 | 1242 | 1272 | 1248 | -30 | -7 | 23 |
| Women | 70-79 y | 63.2 | 162.2 | 1231 | 1259 | 1217 | -29 | 14 | 42 |

kcal/d: kilocalories per day; kg: kilograms; m: meters; MJ/d; megajoules per day; REE: resting energy expenditure; y: years

[a] REE is calculated in MJ/d and converted into kcal/d as follows: REE in MJ/d / 4.184 * 1000.

**Table D2** Predicted resting energy expenditure for various sex- and age-groups of children, based on the equations developed by Henry (2005)[15] and Schofield (1985)[30], and by application of Dutch reference values for body weight and height

| Sex | Age group | Dutch reference weight (kg) | Dutch reference height (cm) | REE predicted with equations developed by Henry (kcal/d) | REE predicted with equations developed by Schofield (kcal/d)[b] | Difference in REE: Henry versus Schofield (kcal/d) |
|---|---|---|---|---|---|---|
| Boys | 1 y | 10.1 | 76.7 | 573 | 548 | 25 |
| Boys | 2 y | 12.9 | 88.4 | 752 | 726 | 26 |
| Boys | 3 y | 15.2 | 97.8 | 842[a] | 840 | 2 |
| Boys | 4 y | 17.3 | 105.5 | 898[a] | 891 | 7 |
| Boys | 5 y | 19.6 | 113.2 | 956[a] | 946 | 10 |
| Boys | 6 y | 22.0 | 119.9 | 1014[a] | 1002 | 12 |
| Boys | 7 y | 24.5 | 126.2 | 1071[a] | 1059 | 12 |
| Boys | 8 y | 27.4 | 132.5 | 1135[a] | 1125 | 10 |
| Boys | 9 y | 30.5 | 138.5 | 1200[a] | 1193 | 7 |
| Boys | 10 y | 33.5 | 143.7 | 1204 | 1257 | -53 |
| Boys | 11 y | 36.9 | 149.0 | 1271 | 1320 | -49 |
| Boys | 12 y | 41.3 | 155.2 | 1356 | 1400 | -44 |
| Boys | 13 y | 46.5 | 161.8 | 1455 | 1493 | -38 |
| Boys | 14 y | 52.2 | 168.5 | 1562 | 1595 | -33 |
| Boys | 15 y | 58.3 | 175.2 | 1675 | 1703 | -28 |
| Boys | 16 y | 65.7 | 179.1 | 1800 | 1829 | -29 |
| Boys | 17 y | 67.2 | 181.0 | 1829 | 1856 | -27 |
| Girls | 1 y | 9.5 | 75.0 | 529 | 508 | 21 |
| Girls | 2 y | 12.3 | 87.1 | 699 | 678 | 21 |
| Girls | 3 y | 14.7 | 97.0 | 786 | 778 | 8 |
| Girls | 4 y | 16.9 | 104.9 | 838 | 828 | 10 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Girls | 5 y | 19.1 | 112.1 | 888 | 877 | 11 |
| Girls | 6 y | 21.5 | 118.8 | 940 | 928 | 12 |
| Girls | 7 y | 24.1 | 125.3 | 995 | 983 | 12 |
| Girls | 8 y | 26.9 | 131.3 | 1052 | 1040 | 12 |
| Girls | 9 y | 30.1 | 137.3 | 1116 | 1104 | 12 |
| Girls | 10 y | 34.0 | 143.5 | 1139 | 1153 | -14 |
| Girls | 11 y | 38.4 | 149.7 | 1196 | 1218 | -22 |
| Girls | 12 y | 43.2 | 155.7 | 1256 | 1286 | -30 |
| Girls | 13 y | 47.6 | 160.8 | 1310 | 1347 | -37 |
| Girls | 14 y | 51.0 | 164.5 | 1351 | 1393 | -42 |
| Girls | 15 y | 53.2 | 166.9 | 1378 | 1422 | -44 |
| Girls | 16 y | 57.8 | 168.3 | 1424 | 1467 | -43 |
| Girls | 17 y | 58.3 | 169.2 | 1431 | 1476 | -45 |

kcal/d: kilocalories per day; kg: kilograms; m: meters; MJ/d; megajoules per day; REE: resting energy expenditure; y: years

[a] There seems to be an error in Henry's equation for REE in kcal/d for boys aged 3-10 years old. Therefore, for this group, Henry's equation for REE in MJ/d was used and the REE was converted into kcal/d as follows: REE in MJ/d / 4.184 * 1000.

[b] REE was calculated in MJ/d and converted into kcal/d as follows: REE in MJ/d / 4.184 * 1000.

# Annex E
# Estimated AR based on an additive or multiplication factor for growth

**Table E1** Energy required for tissue growth and the average energy requirement for various sex- and age-groups of children, determined by using the additive model or the multiplication factor and by application of Dutch reference values for body weight, height and body weight gain

| Sex | Age group | Dutch reference weight gain (kg/y) | Dutch reference weight gain (g/d)[a] | Energy deposition (kcal/d)[b] | TEE (REE * PAL) (kcal/d)[c,d] | Energy deposited as percentage of TEE[e] | AR calculated based on additive model (TEE + 2 kcal/g) | AR calculated using multiplication factor (TEE * 1.01) | Difference between AR additive model and multiplication factor (kcal/d) |
|---|---|---|---|---|---|---|---|---|---|
| Boys | 1-2 y | 2.8 | 7.7 | 15.3 | 802 | 1.9 | 817 | 810 | 7 |
| Boys | 2-3 y | 2.3 | 6.3 | 12.6 | 1053 | 1.2 | 1066 | 1064 | 2 |
| Boys | 3-4 y | 2.1 | 5.8 | 11.5 | 1178 | 1.0 | 1190 | 1190 | 0 |
| Boys | 4-5 y | 2.3 | 6.3 | 12.6 | 1436 | 0.9 | 1449 | 1450 | -1 |
| Boys | 5-6 y | 2.4 | 6.6 | 13.2 | 1530 | 0.9 | 1543 | 1546 | -3 |
| Boys | 6-7 y | 2.5 | 6.8 | 13.7 | 1622 | 0.8 | 1636 | 1638 | -2 |
| Boys | 7-8 y | 2.9 | 7.9 | 15.9 | 1714 | 0.9 | 1730 | 1731 | -1 |
| Boys | 8-9 y | 3.1 | 8.5 | 17.0 | 1815 | 0.9 | 1832 | 1834 | -2 |
| Boys | 9-10 y | 3.0 | 8.2 | 16.4 | 1920 | 0.9 | 1937 | 1940 | -3 |
| Boys | 10-11 y | 3.4 | 9.3 | 18.6 | 2167 | 0.9 | 2186 | 2189 | -3 |
| Boys | 11-12 y | 4.4 | 12.1 | 24.1 | 2288 | 1.1 | 2312 | 2311 | 1 |
| Boys | 12-13 y | 5.2 | 14.2 | 28.5 | 2441 | 1.2 | 2469 | 2465 | 4 |
| Boys | 13-14 y | 5.7 | 15.6 | 31.2 | 2619 | 1.2 | 2650 | 2645 | 5 |
| Boys | 14-15 y | 6.1 | 16.7 | 33.4 | 2811 | 1.2 | 2844 | 2839 | 5 |
| Boys | 15-16 y | 7.4 | 20.3 | 40.5 | 3014 | 1.3 | 3055 | 3044 | 11 |
| Boys | 16-17 y | 1.5 | 4.1 | 8.2 | 3241 | 0.3 | 3249 | 3273 | -24 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Boys | 17-18 y | 1.0 | 2.7 | 5.5 | 3292 | 0.2 | 2397 | 3325 | -28 |
| Girls | 1-2 y | 2.8 | 7.7 | 15.3 | 741 | 2.1 | 756 | 748 | 8 |
| Girls | 2-3 y | 2.4 | 6.6 | 13.2 | 979 | 1.3 | 992 | 989 | 3 |
| Girls | 3-4 y | 2.2 | 6.0 | 12.1 | 1101 | 1.1 | 1113 | 1112 | 1 |
| Girls | 4-5 y | 2.2 | 6.0 | 12.1 | 1341 | 0.9 | 1353 | 1354 | -1 |
| Girls | 5-6 y | 2.4 | 6.6 | 13.2 | 1421 | 0.9 | 1434 | 1435 | -1 |
| Girls | 6-7 y | 2.6 | 7.1 | 14.2 | 1505 | 0.9 | 1519 | 1520 | -1 |
| Girls | 7-8 y | 2.8 | 7.7 | 15.3 | 1593 | 1.0 | 1608 | 1608 | 0 |
| Girls | 8-9 y | 3.2 | 8.8 | 17.5 | 1684 | 1.0 | 1701 | 1701 | 0 |
| Girls | 9-10 y | 3.9 | 10.7 | 21.4 | 1785 | 1.2 | 1807 | 1803 | 4 |
| Girls | 10-11 y | 4.4 | 12.1 | 24.1 | 2050 | 1.2 | 2074 | 2071 | 3 |
| Girls | 11-12 y | 4.8 | 13.2 | 26.3 | 2152 | 1.2 | 2179 | 2174 | 5 |
| Girls | 12-13 y | 4.4 | 12.1 | 24.1 | 2260 | 1.1 | 2285 | 2283 | 2 |
| Girls | 13-14 y | 3.4 | 9.3 | 18.6 | 2358 | 0.8 | 2376 | 2381 | -5 |
| Girls | 14-15 y | 2.2 | 6.0 | 12.1 | 2432 | 0.5 | 2444 | 2456 | -12 |
| Girls | 15-16 y | 4.6 | 12.6 | 25.2 | 2480 | 1.0 | 2505 | 2505 | 0 |
| Girls | 16-17 y | 0.5 | 1.4 | 2.7 | 2564 | 0.1 | 2567 | 2590 | -23 |
| Girls | 17-18 y | 0.3 | 0.8 | 1.6 | 2576 | 0.1 | 2578 | 2602 | -24 |

AR: average requirement; d: days; g: grams; kcal: kilocalories; kg: kilograms; m: meters; MJ/d; megajoules per day; PAL: physical activity level; REE: resting energy expenditure; TEE: total energy expenditure; y: years

[a] Calculated as: Reference weight gain in kg/y / 365 * 1000.

[b] Calculated as: Reference weight gain in g/d * 2 kcal/g.

[c] For these calculations, the REE was predicted using the Henry equations based on Dutch reference values for body weight and height.

[d] For these calculations, the following PAL values were applied: 1.4 for those aged 1-2 to 3-4 y, 1.6 for those aged 4-5 to 9-10 y and 1.8 for those aged 10-11 to 17-18 y.

[e] Calculated as: Energy deposition in kcal/d / TEE * 100.

# Annex F
# REE data of lactating and non-lactating women

**Table F1** Resting energy expenditure measured in lactating and non-lactating women

| Reference | Country | n | State (months pp) | Body weight (kg) | REE (kcal/d)[a] | Difference in REE to non-lactating state (kcal/d)[b] | *P*-value[a] | Difference in REE to non-lactating state (%)[b] |
|---|---|---|---|---|---|---|---|---|
| Butte et al., 2001[75] | USA | 24 | NPNL, post | 61.6 | 1350 | – | – | – |
| | | | L (3) | 62.8 | 1331 | -19 | 0.21 | -1.4 |
| Forsum et al., 1992[71] | Sweden | 23 | NPNL, pre | 61.5 | 1338 | – | – | – |
| | | | L (2) | 64.4 | 1410 | +72 | <0.05 | +5.4 |
| | | | L (6) | 63.0 | 1434 | +96 | <0.05 | +7.1 |
| Goldberg et al., 1991[77] | UK | 10 | NPNL, post | 57.1 | 1400 | – | – | – |
| | | | L (1) | 58.9 | 1407 | +7 | NS | +0.5 |
| | | | L (2) | 58.9 | 1397 | -3 | NS | -0.2 |
| | | | L (3) | 58.6 | 1346 | -54 | NS | -3.9 |
| Illingworth et al., 1986[78] | USA | 12 | NPNL, post | 64.9 | 1030 | – | – | – |
| | | | L (2) | 66.5 | 1042 | +12 | NS | +1.2 |
| Kopp-Hoolihan et al., 1999[73] | USA | 10 | NPNL, pre | Fat mass: 19.6[c] | 1314 | – | – | – |
| | | | L (1-1,5) | Fat mass: 21,8[c] | 1329 | +15 | NS | +1.2 |
| Spaaij et al., 1994[79] | The Netherlands | 24 | NPNL, pre | 62.4 | 1319 | – | – | – |
| | | | L (2) | 64.4 | 1382 | +62 | <0.03 | +4.7 |

kcal/d: kilocalories per day; L: lactating; NPNL: non-pregnant, non-lactating; pre: pre-conception; post: post-lactation; pp: postpartum; REE: resting energy expenditure; UK: United Kingdom; USA: United States of America

[a] Values obtained from respective publication.

[b] Values not shown in publications, but calculated by the Committee based on the REE values reported.

[c] Body weight was not reported.

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