

### Appendix 3: Energy Learning Opportunities at Schools in Hamburg / Germany

**Table 1** Learning opportunities that explicitly reference the energy concept in Hamburg/Germany, where testing for the presented study was conducted. The shown contents refer to the compulsory standards for general science classes at primary level (FHH-BSB, 2011a, b; 2014a), middle school at both high-performance (Gymnasium: FHH-BSB, 2011c,d,e) and mixed performance schools (Stadtteilschule: FHH-BSB, 2014b, c, d), as well as in high schools (both school types: FHH-BSB, 2009a,b,c). The referenced standards encompass the German national science standards (KMK, 2005a, b, c) and therefore include energy as a disciplinary core idea and a concept to link the science disciplines.

Due to the large number of learning opportunities, the table does not distinguish between learning opportunities of different school types, as their overlap was considerable. Several points represent summaries of more extensive sections in the standards. Translations are as direct as reasonable and include conceptually critical formulations

Grade level	General science
<b>1-4</b> General science at elementary School	<p><i>By the end of grade 2:</i></p> <ul style="list-style-type: none"> <li>- Reasons for energy requirements of humans, animals and plants</li> <li>- Reasons for energy requirements of technical appliances</li> <li>- Possibilities for saving energy in daily life</li> </ul> <p><i>By the end of grade 4:</i></p> <ul style="list-style-type: none"> <li>- Energy requirements and energy transformations in living beings (nutrition and digestion)</li> <li>- Energy transformation in technical appliances (e.g. electricity is transformed into light, heat and movement)</li> <li>- Sources of electrical energy (conventional vs. regenerative)</li> <li>- Measures of saving/cutting down on energy with respect to climate protection</li> </ul>
<b>5-6</b> Science / Technology at lower secondary level	<ul style="list-style-type: none"> <li>- Explaining heat by using the particle model</li> <li>- The relationship between heat and energy</li> </ul>

Grade level	Biology	Chemistry	Physics
<p>7-10 / 11 (Gymnasium / Stadtteilschule)</p> <p>Middle school</p>	<ul style="list-style-type: none"> <li>- Matter- and energy transformations in cells and organisms</li> <li>- Matter cycles and energy flow in ecosystems</li> </ul>	<p><b>By the end of grade 8:</b></p> <ul style="list-style-type: none"> <li>- Matter-and energy transformation through particle- and structural reorganization, as well as through the reforming of chemical bonds</li> <li>- Phenomena of matter and energy transformations in chemical reactions</li> <li>- Differentiation between matter-/energy-transformations and physical processes in chemical reactions</li> <li>- Dependence of the energy content of reaction systems on the exchange with the environment</li> <li>- Explaining energetic phenomena in reactions by the transformation of stored energy into other energy forms</li> </ul> <p><b>Additional contents until the end of grade 11:</b></p> <p><i>Competence domain 'content'</i></p> <ul style="list-style-type: none"> <li>- Description of matter-/energy-transformations via changes at particle level and re-formations of chemical bonds</li> </ul>	<p><b>By the end of grade 8:</b></p> <p><i>Competence domain 'content'</i></p> <ul style="list-style-type: none"> <li>- Electrical energy is represented by the dimension voltage and measured by the unit Volt.</li> <li>- Energy appears in different forms, which can be transformed into each other.</li> <li>- Energy can be transferred.</li> <li>- Energy is conserved.</li> <li>- In an electric circuit, energy is transferred from the source to a transducer.</li> </ul> <p><i>Competence domain 'knowledge discovery'</i></p> <ul style="list-style-type: none"> <li>- Description of natural processes by using the energy concept</li> <li>- Possibilities to limit loss of thermal energy</li> <li>- Hints for saving energy in school and everyday life</li> </ul> <p><b>Additional contents until the end of grade 11:</b></p> <p><i>Competence domain 'content'</i></p> <ul style="list-style-type: none"> <li>- Terms: temperature, thermal energy, heat flow, heat conductivity</li> <li>- Comparison of energy transducers respective their electrical properties</li> <li>- Kinetic energy and energy forms during free fall</li> <li>- Gravitational potential, kinetic, electrical potential and thermal energy</li> <li>- Efficiency as a measure of energy degradation</li> <li>- Relation between power, energy and time</li> <li>- Comparison of different types of power stations</li> <li>- Function of energy transducers (e.g. dynamo, combustion engine)</li> <li>- Units of different energy forms and power</li> <li>- Regenerative energy sources and the related energy transformations</li> <li>- Formulas: <math>E_{\text{pot}} = m \cdot g \cdot h</math>, <math>E_{\text{kin}} = \frac{1}{2} \cdot m \cdot v^2</math>; <math>Q = c \cdot m \cdot \Delta t</math>; <math>E = P \cdot t</math></li> <li>- Mass and energy can be transformed into each other.</li> </ul>

Grade level	Biology	Chemistry	Physics
<p><b>7-10 / 11</b> (Gymnasium / Stadtteilschule)</p> <p>Middle school</p> <p><b>- continued -</b></p>		<p><i>Competence domain 'evaluation'</i></p> <ul style="list-style-type: none"> <li>- Value, production and processing of fossil and alternative energy carriers</li> <li>- Applicability of fuel cells for energy transformations</li> </ul>	<p><i>Competence domain 'knowledge discovery'</i></p> <ul style="list-style-type: none"> <li>- Application of measurement devices to determine energy consumption, power, as well as amounts and costs of energy</li> <li>- Determination of caloric values</li> <li>- Using energy conservation for argumentation</li> <li>- Application of the above-mentioned formulas in simple problems</li> <li>- Calculation and estimation of efficiencies</li> </ul> <p><i>Competence domain 'communication'</i></p> <ul style="list-style-type: none"> <li>- Representation of energy transformations in block diagrams</li> <li>- Analysis of energy cost and consumption</li> </ul> <p><i>Competence domain 'evaluation'</i></p> <ul style="list-style-type: none"> <li>- Magnitudes of energy consumption in the private sector</li> <li>- Deriving hints for saving energy</li> <li>- Comparing energy transducers respective their efficiencies</li> <li>- Formulating statements for the responsible application of primary energy sources</li> <li>- Climate change with respect to the greenhouse effect and global warming</li> <li>- Application of ionizing radiation in nuclear power with respect to energy and energy utilization</li> <li>- Radiated energy from the sun as a product of fusion reactions</li> </ul>

<p><b>11 / 12-12 / 13</b> (Gymnasium / Stadtteilschule)</p> <p>High school</p>	<p><i>Metabolism and energy turnover:</i></p> <ul style="list-style-type: none"> <li>- Cell architecture and organelles</li> <li>- Enzyme reactions</li> <li>- Photosynthesis</li> <li>- Respiration and fermentation</li> <li>- Energy transformation in cells and energy transfer via ATP</li> </ul>	<ul style="list-style-type: none"> <li>- Energy turnover describes all chemical reactions.</li> <li>- Quantitative and qualitative aspects of understanding the energy concept</li> <li>- Simple reactions and complex reaction systems</li> <li>- Energy und kinetics of chemical reactions</li> </ul>	<p>Consolidation and integration of contents from the lower secondary grades, especially with respect to:</p> <ul style="list-style-type: none"> <li>- The field concept</li> <li>- The wave concept</li> <li>- The particle concept</li> <li>- The quantum concept</li> </ul>
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<p><b>11-12 / 13</b> (Gymnasium / Stadtteilschule)</p> <p>High school</p> <p><b>- continued -</b></p>	<p><i>Core idea matter- and energy transformations:</i> - Living beings as open systems - Applications concerning photosynthesis, the carbon cycle and energy flow through ecosystems</p> <p><i>Competence domain 'methods'</i> - Application of biology-specific explanatory models, e.g. in the ATP/ADP transfer system - Application of models, e.g. for energy flow</p> <p><i>Competence domain 'communication'</i> - Comprehensible, structured and terminologically adequate presentation of contents, e.g. by using matter cycles or energy flow</p>	<p><i>Competence domain 'content'</i> - Looking at matter transformations from an energy perspective: Influence of catalysts on chemical reactions</p> <p><i>Competence domain 'evaluation'</i> - Impact of applied chemistry on securing food and energy supply - Impact of applied chemistry on the production of materials</p>	
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	<p><i>Competence domain 'evaluation'</i></p> <ul style="list-style-type: none"><li>- Evaluation of everyday phenomena from a biological perspective, e.g. respective regenerative natural resources as energy sources</li></ul>		
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- FHH-BSB - Freie und Hansestadt Hamburg Behörde für Schule und Berufsbildung (2009a). *Bildungsplan Gymnasium - Gymnasiale Oberstufe - Biologie*. Hamburg: Behörde für Schule und Berufsbildung.
- FHH-BSB - Freie und Hansestadt Hamburg Behörde für Schule und Berufsbildung (2009b). *Bildungsplan Gymnasium - Gymnasiale Oberstufe - Chemie*. Hamburg: Behörde für Schule und Berufsbildung.
- FHH-BSB - Freie und Hansestadt Hamburg Behörde für Schule und Berufsbildung (2009c). *Bildungsplan Gymnasium - Gymnasiale Oberstufe - Physik*. Hamburg: Behörde für Schule und Berufsbildung.
- FHH-BSB - Freie und Hansestadt Hamburg Behörde für Schule und Berufsbildung (2011a). *Bildungsplan Grundschule - Sachunterricht*. Hamburg: Behörde für Schule und Berufsbildung.
- FHH-BSB - Freie und Hansestadt Hamburg Behörde für Schule und Berufsbildung (2011b). *Bildungsplan Gymnasium - Sekundarstufe I - Naturwissenschaften/Technik*. Hamburg: Behörde für Schule und Berufsbildung.
- FHH-BSB - Freie und Hansestadt Hamburg Behörde für Schule und Berufsbildung (2011c). *Bildungsplan Gymnasium - Sekundarstufe I - Biologie*. Hamburg: Behörde für Schule und Berufsbildung.
- FHH-BSB - Freie und Hansestadt Hamburg Behörde für Schule und Berufsbildung (2011d). *Bildungsplan Gymnasium - Sekundarstufe I - Chemie*. Hamburg: Behörde für Schule und Berufsbildung.
- FHH-BSB - Freie und Hansestadt Hamburg Behörde für Schule und Berufsbildung (2011e). *Bildungsplan Gymnasium - Sekundarstufe I - Physik*. Hamburg: Behörde für Schule und Berufsbildung.
- FHH-BSB - Freie und Hansestadt Hamburg Behörde für Schule und Berufsbildung (2014a). *Bildungsplan Stadtteilschule - Jahrgangsstufen 5 / 6 - Naturwissenschaften / Technik*. Hamburg: Behörde für Schule und Berufsbildung.
- FHH-BSB - Freie und Hansestadt Hamburg Behörde für Schule und Berufsbildung (2014b). *Bildungsplan Stadtteilschule - Jahrgangsstufen 7-11 - Biologie*. Hamburg: Behörde für Schule und Berufsbildung.
- FHH-BSB - Freie und Hansestadt Hamburg Behörde für Schule und Berufsbildung (2014c). *Bildungsplan Stadtteilschule - Jahrgangsstufen 7-11 - Chemie*. Hamburg: Behörde für Schule und Berufsbildung.
- FHH-BSB - Freie und Hansestadt Hamburg Behörde für Schule und Berufsbildung (2014d). *Bildungsplan Stadtteilschule - Jahrgangsstufen 7-11 - Physik*. Hamburg: Behörde für Schule und Berufsbildung.
- KMK - Ständige Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland (2005a). *Bildungsstandards im Fach Biologie für den Mittleren Schulabschluss - Beschluss vom 16.12.2004*. München: Luchterhand.
- KMK - Ständige Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland (2005b). *Bildungsstandards im Fach Chemie für den Mittleren Schulabschluss: Beschluss vom 16.12.2004*. München: Luchterhand.
- KMK - Ständige Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland (2005c). *Bildungsstandards im Fach Physik für den Mittleren Schulabschluss Beschluss vom 16.12. 2004*. München: Luchterhand.