Geosynthetic Institute
475 Kedron Avenue
Folsom, PA 19033-1208 USA
TEL (610) 522-8440
FAX (610) 522-8441

GRI White Paper #22

Selected Geosynthetic Opportunities Associated with Energy Production and Transmission

by

Robert M. Koerner, Ph.D., P.E., NAE
Director Emeritus – Geosynthetic Institute
Professor Emeritus – Drexel University
610-522-8440
robert.koerner@coe.drexel.edu

George R. Koerner, Ph.D., P.E., CQA
Director – Geosynthetic Institute
610-522-8440
gkoerner@dca.net

June 8, 2012

Geosynthetic Opportunities Associated With Energy Production and Transmission

by

Bob and George Koerner
Geosynthetic Institute

Introduction

In subdividing the many application areas of geosynthetics one usually focuses on transportation, geotechnical, geoenvironmental, hydraulics and smaller areas such as mining, agriculture, aquaculture, etc. An added and seldomly discussed application area, however, is to consider primary energy sources and then to investigate the various geosynthetic opportunities in each specific source area. This particular approach is taken in this white paper stimulated largely by the present intense activity in shale gas plays.

The worldwide energy situation is given in Figure 1 wherein the traditional source types are oil, coal, gas, hydro and nuclear representing 95% of the total. Within the recent renewables are wind power, solar energy, biomass, biofuel and geothermal sources.

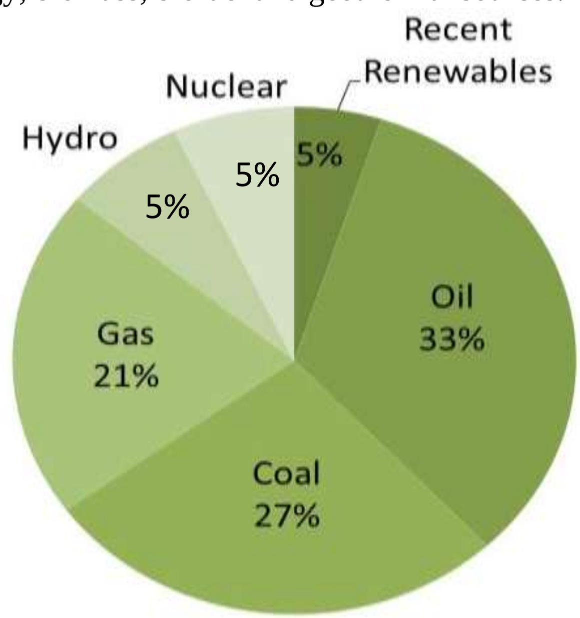

Figure 1. Energy sources in the world (compl. IEA-Wikipedia).

Using the collective energy from all of these sources gives an interesting worldwide perspective as to the present status.   Even further, see the following listing of individual energy consumption in units of kWh/capita (from IEQ/OECD Wikipedia) and at least one projection in Figure 2 as to what the future might hold.

- USA – 87,215
- EU-27 – 40,821
- Middle East – 34,774
- China – 18,608
- Latin America – 14,421
- Africa – 7,792
- India – 6,280
- The World – 21,283

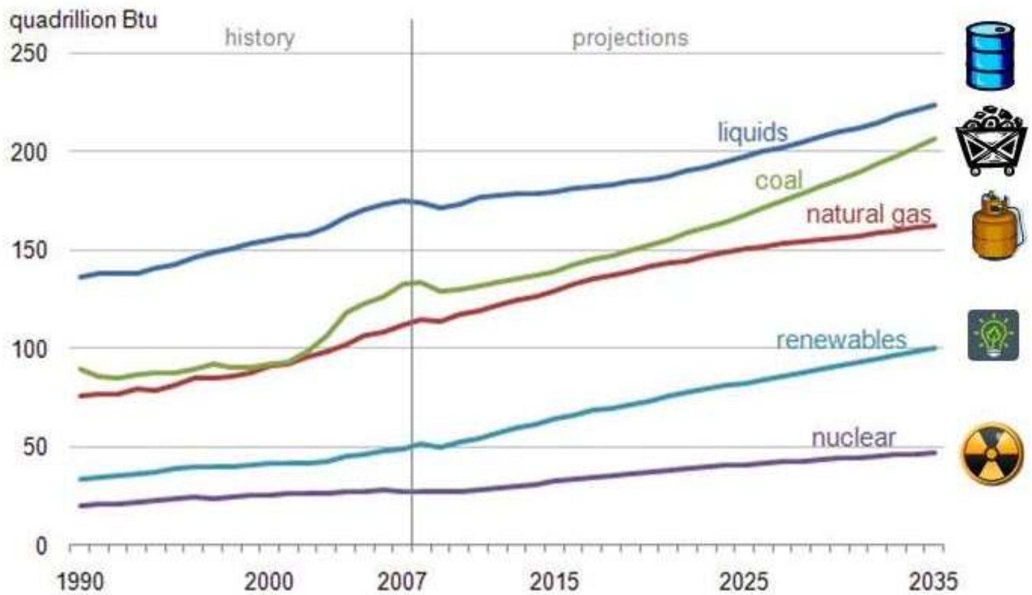

Figure 2. Worldwide primary energy use by fuel type.
Source: U.S. Energy Information Administration
Report #: DOE/EIA-0484 (2010)

Using this global picture as background information, this white paper addresses the major geosynthetic opportunities (present and possibly future) within the various individual energy sources.

1.0 Geosynthetics in Oil Production, Transportation and Storage

Oil, of course, consists of a well drilling and pumping operations which (when recovered) must then be transported, converted and stored or directly used as an energy source. The major geosynthetics applications with respect to oil operations appear to be as follows:

1. Paved and unpaved road construction using geotextiles and/or geogrids to access the well site and storage locations.
2. Geomembrane liners at the well site to control surface contamination.
3. Geomembranes as secondary liners for storage tanks and tank farms; see Figure 3.
4. Plastic pipe (geopipe?) at almost every stage of the operation.
5. The uniqueness of oil sands represent opportunities for final covers of the spoil as well as control of numerous environmental contamination situations.

Figure 3. Geomembranes used as secondary containment for tank farms, gas stations, etc.

2.0 Geosynthetics in Coal Mining, Transportation, Storage and Waste Disposal

Coal, the classic energy source, is either mined at depth or strip mined from the surface. The major geosynthetics applications with respect to coal operations appear to be as follows:

1. Paved and unpaved roads using geotextiles and/or geogrids to access the mining operation and for transportation to the shipping site.
2. Numerous environmental contamination controls such as erosion control materials, silt fences and sedimentation pond liners.
3. Mine safety applications using various geosynthetic materials.
4. Mechanically stabilized earth stabilization berms and final cover for coal spoil tips.
5. Mechanical stabilized earth (MSE) walls and slopes for coal combustion residuals (CCR's) such as fly ash, bottom ash, flue gas desulfurization materials, and boiler slag. This applies to both dry disposal as well as slurried disposal, see Figure 4.

Figure 4. Recent failures of dry and wet disposal of coal combustion residuals.

3.0 Geosynthetics in Natural Gas Production and Transportation

Natural gas is available in various forms, see Figure 5, but shale gas recovery relies on horizontal drilling and hydrofracing and is currently under rapid development. In fact, its availability is so plentiful that it is influencing the entire energy pricing structure. In this regard, one can expect the energy distribution graphics of Figures 1 and 2 to change significantly in the near future.

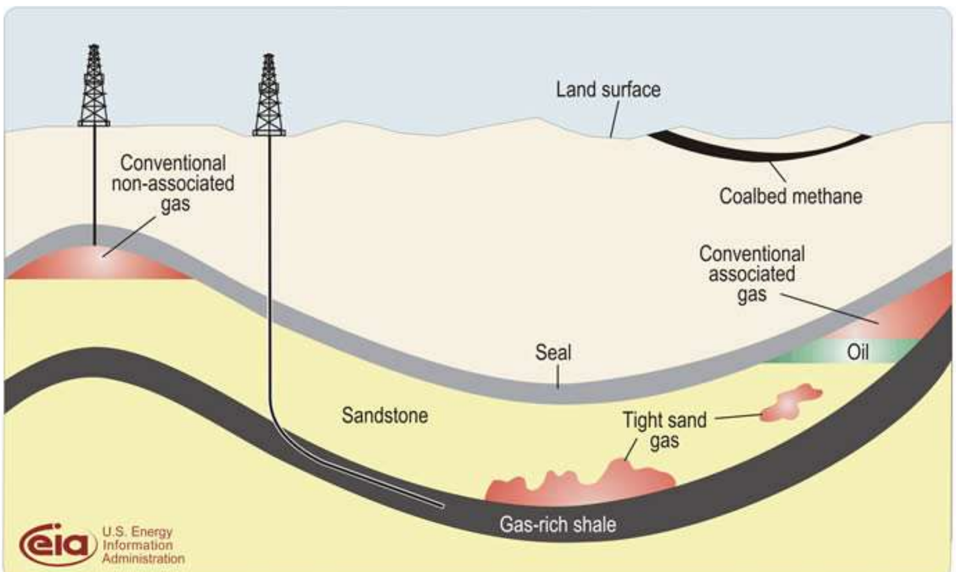

Figure 5. Various types of natural gas (compl. EIA).

The major geosynthetic applications with respect to natural gas operations, particularly shale gas plays, appear to be as follows (see Figure 6).

1. Geomembrane liners for fresh water storage and use.
2. Double lined geomembrane systems for frac water and production water storage, sedimentation and reuse.
3. Double lined geomembrane systems for disposal of vertical and horizontal well cuttings.
4. Geomembrane contamination prevention liner mats in the immediate well drilling vicinity.

5. Rigid and transportable polymeric working mats (3-D cells) at the well drilling area.
6. Local paved road widening and reconstruction using geotextiles and/or geogrids for access to these remote sites.
7. Unpaved road construction using geogrids and/or geotextiles leading from the local paved roads to the well pad and its related operations.
8. Mechanically stabilized earth (MSE) walls and slopes using geosynthetic reinforcement to provide level surfaces for operations and materials storage.
9. Erosion control materials (of all types) to control slope and channel erosion from occurring.
10. Large amounts of plastic pipe (HDPE and PVC) for fresh water, frac/production water as well as the final gas product transmission.

Figure 6. Overview of shale gas well drilling site and typical congestion of multiple operations (compl. Wikipedia).

4.0 Geosynthetics in Hydroelectric Power Production

Hydroelectricity provides power by virtue of the gravitational force of falling or flowing water. The various forms are conventional dams, pumped storage, run-of-the-river, tidal, and underground (waterfall or lake). While Figure 1 shows that only 3% of power is from this source, more recent reports claim the figure is as high as 16%. The three new huge dams in China, Brazil and Venezuela likely account for some of the increase. Nevertheless, hydroelectricity power generation has been practiced for centuries. Bulletin No. 135 of the International Committee on Large Dams (ICOLD) shows that 250 dams have been constructed with geomembranes as waterproofing barriers, see Table 1.

Table 1. Dams With Geomembrane Waterproofing
(ref., ICOLD Bulletin No. 135, 2010)

Type of Dam	Height (m)	Number	Percentage
Earth or rock fill	116	174	69.6
Concrete or masonry	174	43	17.2
Roller compacted concrete	188	32	12.8
Unknown	-	1	0.4
Total	-	250	100.0

More than half of the above are rehabilitation projects only initiated after excessive seepage or cracking of the structure has occurred. Photographs of these three dam types are shown in Figure 7.

(a) Earth fill dam (b) Concrete dam (c) Roller compacted concrete dam

Figure 7. Various dam remediation projects (compl. CARPI Tech BV).

A significant variation of conventional dams for water storage and hydroelectric generation is pumped-storage hydroelectricity. It relies on load balancing for its economy; see Figure 8. The method stores energy in the form of impounded water, pumped from a lower elevation reservoir to one at a higher elevation. Low cost off-peak electric power is used to run the pumps. During periods of high electrical demand, the stored water is released through turbines to produce electric power. Although the losses of the pumping process makes the plant a net consumer of energy overall, the system increases revenue by selling more electricity during period of peak demand, when electricity prices are the highest.

The major geosynthetic applications with respect to hydroelectricity generation appear to be as follows:

1. Geomembrane and geosynthetic clay liners for upper and lower reservoir liners for pumped storage hydroelectricity.
2. Geomembrane waterproofing on the upstream face of earth fill, concrete and roller compacted dams.
3. Geonet, geocomposite and geotextile drainage materials between the dam and the waterproofing geomembrane.
4. Thick needle punched nonwoven geotextiles as geomembrane protection materials.
5. Geomembrane and/or geosynthetic clay liner waterproofing of the channels leading water to the generation station.
6. Tunnel waterproofing with geomembranes for discharge from the dam to the generating station.
7. Obviously, large amount of plastic pipe to convey water to the end user.

Figure 8. Concept and example of pumped-storage method of generating hydroelectricity (compl. U. S. Bureau of Reclamation)

5.0 Geosynthetics in Nuclear Power Generation

Within nuclear power generation plants there are limited geosynthetic opportunities (other than conventional geosynthetics used at all heavy construction sites) with the notable exception of containment of the subsequent radioactive waste. In this regard there is high level radioactive waste (HLRW), transuranic liquid waste (TLW), low level radioactive (LLRW) waste and uranium mill tailings (UMT). The energy levels of HLRW and TLW are generally considered as being such that accelerated degradation of polymeric materials (aka, geosynthetics) will surely occur. That said, LLRW and UMT are clearly candidates for containment and/or encapsulation using geosynthetics. In order to assess the size and scale of such disposal, a survey was conducted and is available as White Paper #18 on the GSI website at www.geosynthetic-institute.org/whitepapers.htm. Included in the summary table are twenty-five UMT sites that are identified consisting of 1893 total acres; thus each site averages about 76 acres in size. The summary table also identifies seven LLRW sites consisting of 1242 total acres; thus each site averages about 177 acres in size.

The major geosynthetic applications with respect to UMT and LLRW disposal appear to be as follows:

1. For new disposal situations complete double lined systems with leak detection are necessary. Thus, geomembranes, geosynthetic clay liners, drainage geocomposites, and geotextiles are all involved.
2. For both new and remediated disposal situations final covers are necessary; see Figure 9. Included are geomembranes, geosynthetic clay liners, drainage geocomposites, geogrid reinforcement and geosynthetic erosion control systems.

3. Geomembranes as vertical cutoff walls for lateral confinement of contaminated groundwater seepage.
4. Geomembranes for lining of disposal boxes containing LLRW such as contaminated equipment, clothing and construction and demolition wastes.

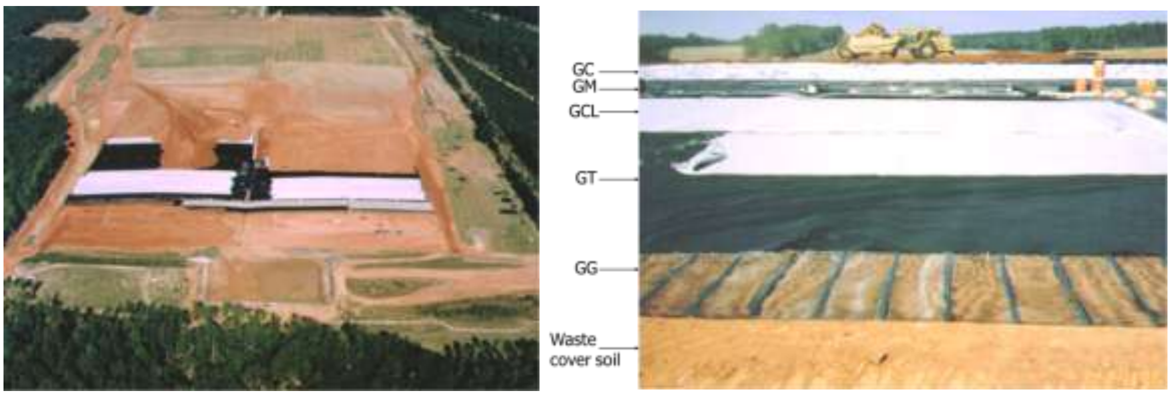

Figure 9. Final cover system over LLRW at a federal disposal site.

6.0 Geosynthetics in Renewable Energy Sources

As noted in the introduction, relatively recent renewables (wind, solar, biomass, biofuel and geothermal) represent a growing percentage of worldwide energy sources. Accompanying their construction and operations there are many geosynthetic applications which (on a site-specific basis) appear to be as follows:

1. Local paved road widening and reconstruction using geotextiles and/or geogrids for access to these generally remote sites.
2. Unpaved road construction using geogrids and/or geotextiles leading from the paved roads to the actual construction site.
3. Portable, and removable, temporary roadways leading from paved roads to the construction site; see Figure 10.
4. High strength geotextiles and/or geogrids for foundation support and stabilization of concrete footings for wind and solar energy sources.
5. Mechanically stabilized earth (MSE) walls and slopes using geosynthetic reinforcement for creating level surfaces for wind and solar energy sources.
6. All types of geosynthetic erosion control and prevention systems since these recent renewables are invariably under strict public scrutiny.

Figure 10. Light and heavy portable access roads (compl. Robusta Mats™).

Summary

The worldwide energy source situation, as well as in every individual country, is constantly with us influencing our daily lives insofar as cost, environmental appropriateness, and even politics are concerned. The projections shown in Figure 2 indicate that the topic has no likelihood in abating. With this assumed as a “given”, the geosynthetics community should focus efforts by being proactive with respect to the various energy sources as applies to federal and state agencies, public advocacy groups, local citizen groups and all related stakeholders. In this regard, the major geosynthetic applications for each energy source appears to be as shown in Table 2.

Table 2. Major Geosynthetic Application Areas as Applies to Various Energy Sources

Geosynthetic Application	Oil	Coal	Nat. Gas	Hydro	Nuclear	Renewals
Pond Liners			√	√		
Waterproofing liners	√			√		
Contamination barriers	√		√		√	
Landfill liners			√		√	
Final covers	√				√	
Paved roads	√	√	√	√	√	√
Unpaved roads	√	√	√	√	√	√
Temporary roads	√		√	√		√
Foundation support						√
MSE walls and slopes		√	√			√
Safety systems	√	√				
Drainage materials			√		√	
Protection materials		√	√			
Erosion control		√	√		√	√
Plastic pipe	√	√	√			

While there are indeed additional geosynthetic applications that can be envisioned, these are the major areas we have seen to date. In this regard, we should be championing our geosynthetic case histories, materials durability, long term performance, benefit/cost advantages, sustainability enhancement, innovative uses and solutions. We have an outstanding chance to exchange knowledge and experiences of successful utilization of geosynthetics throughout every segment of the energy source landscape.